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industrial wiring

Manual for Trainee Electricians

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МОНТАЖ И ЭКСПЛУАТАЦИЯ
ПРОМЫШЛЕННОГО ЭЛЕКТРООБОРУДОВАНИЯ

На английском языке

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Part One

ELECTRIC POWER SUPPLY

Chapter I

THE GENERATION AND USE OF ELECTRIC POWER

1. The General Features of Electric Power Generation and Electric Power Stations

From time immemorial mankind has been using the energy of burning fuels, the wind and falling water.

However, the extensive possibilities of utilising natural sources of energy became available only during a relatively recent period—at the end of the 19th century when, as the result of a series of discoveries and inventions, it became possible to convert the energy of fuels, the wind and falling water into electric power.

Electric power can be easily transmitted over considerable distances, converted into mechanical, heat, light or chemical energy and supplied to any number of consumers.

Electric power is generated in power stations. The principal machine for producing electric power is the generator, a machine with a revolving rotor. To turn the rotor, some kind of engine or turbine, or, as it is called in power engineering, a prime mover is necessary.

Depending upon the kind of energy used by the prime mover, electric power stations are classified as *thermal*, *hydroelectric*, and *wind* power stations.

Thermal and *hydroelectric* power stations are the largest in number and have the greatest industrial significance.

Among the thermal electric power plants, the most widespread are those in which a steam turbine serves as the prime mover for rotating the generator; these are called *steam-turbine* power stations.

Steam-turbine power stations may, in turn, be subdivided into condensing stations, and heat and electric power stations.

Also to be considered in the thermal steam-turbine class are the atomic electric power stations which are acquiring ever greater industrial significance and employ, in place of conventional fuels, an atomic fuel from which the heat necessary for changing the water into steam is obtained by utilising the energy released during splitting of atomic nuclei.

Hydroelectric power stations have prime movers in the form of water turbines and are for this reason called hydroturbine stations. The main generating unit in such stations is a hydrogenerator or water-wheel type generator.

2. *Thermal Electric Power Stations*

Condensing Stations

Condensing electric power stations (Fig. 1) are designed to supply consumers only with electric power.

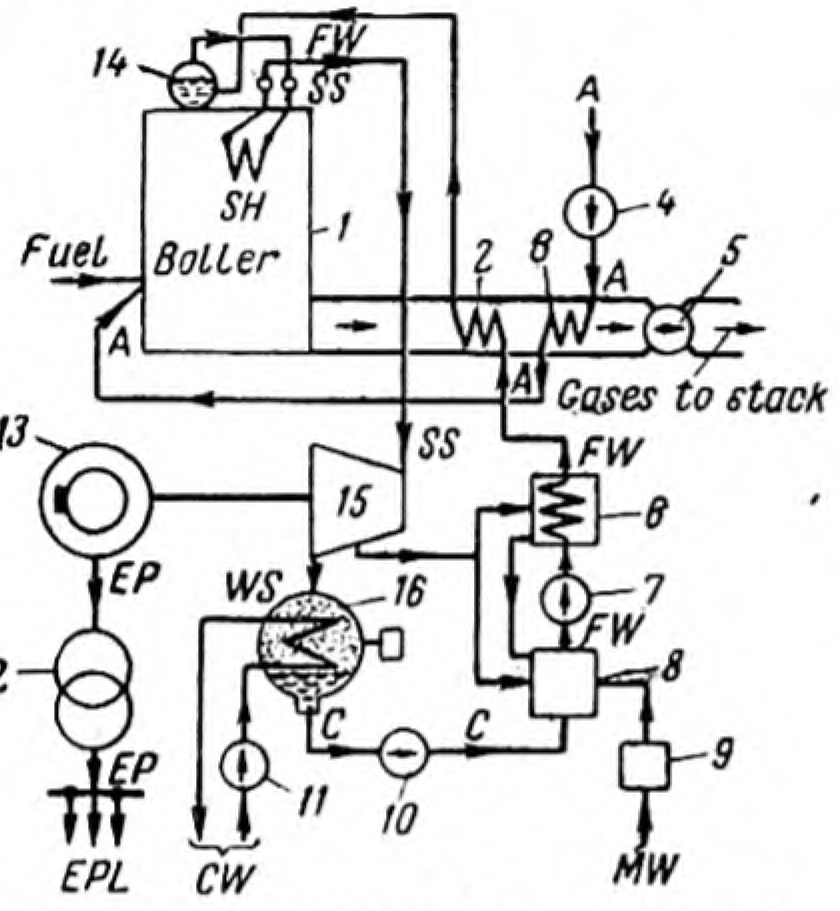


Fig. 1. Basic scheme of a condensing electric power station.

Fig. 1 shows that the fuel, gas in this particular case, is delivered together with the necessary amount of combustion air *A* to the burners in the furnace of boiler *1* where it is burned to build up the temperature required for generating the steam.

By means of induced-draught fan *5*, the gases which begin to accumulate in the boiler furnace are exhausted into the atmosphere through the smoke stack. In their passage they heat the feed water *FW* which flows through economiser *2* before reaching boiler drum *14*. Air *A* is delivered to the furnace by forced-draught fan *4* through air heater *3*.

The steam which is generated in the boiler gathers in drum *14* from which it is passed into superheater *SH*. As the initial conditions of this steam are increased, in particular when it is superheated to a temperature of 550° to 600° C, the efficiency of the power station is noticeably raised. From the superheater the steam *SS* is piped to turbine *15* and turns its rotor which revolves the rotor of generator *13*.

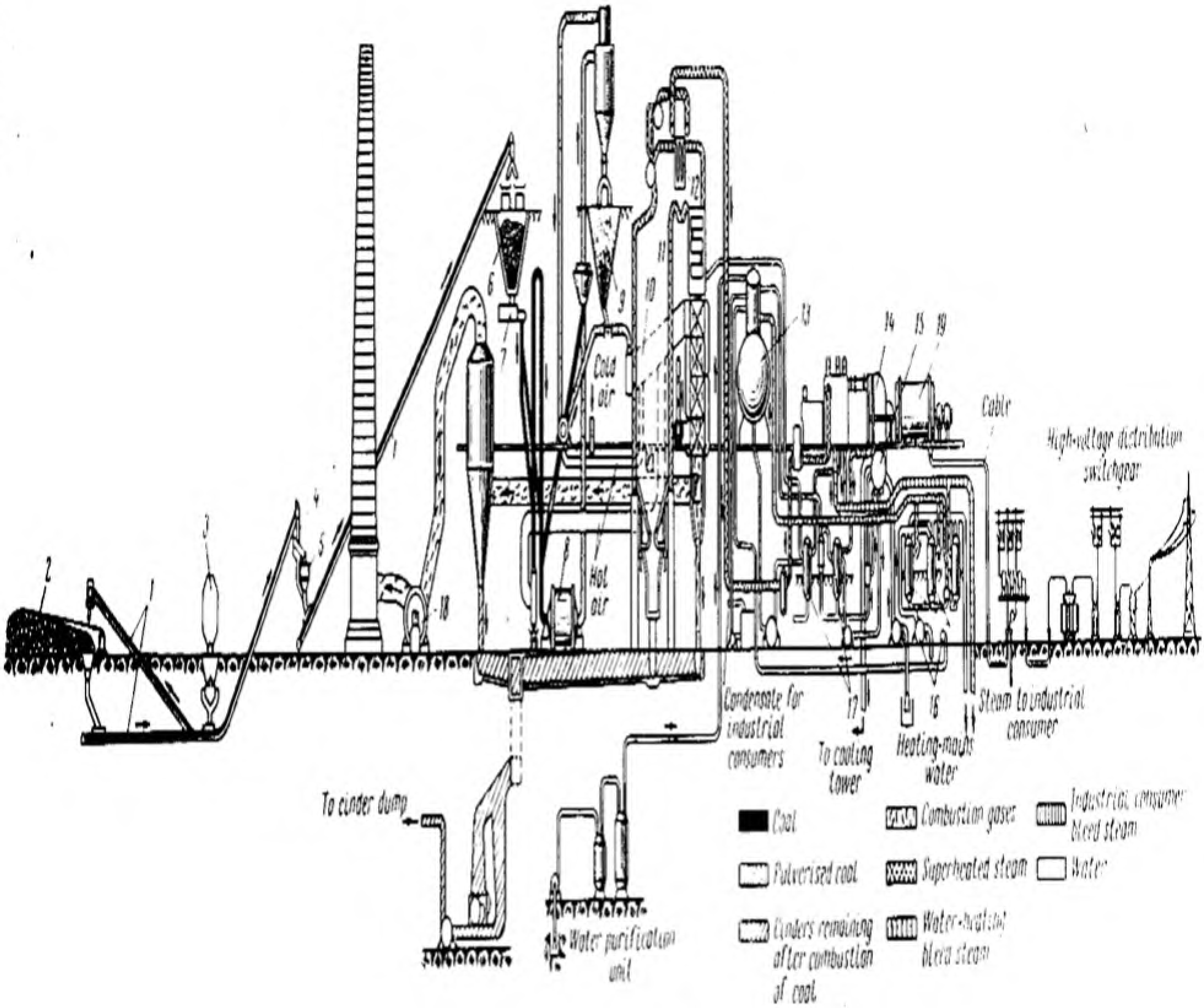
From the turbine the waste (spent) steam *WS* passes into condenser *16* where it is cooled and condensed to water (condensate) by means of circulating water *CW* delivered from a cooling pond by circulating-water pump *11*.

Condensate *C* (precipitated from the steam in the form of water) is then pumped by condensate pump *10* into deaerator *8* from which boiler feed pump *7* delivers it back to boiler drum *14*.

On its path to the boiler, feed water *FW* is heated in feed-water heater *6*. Steam for heating the water both in the deaerator and the feed-water heater is bled from the turbine.

In the deaerator the water is heated to a temperature at which intense liberation of the gases dissolved in the water will take place. These gases, including the dissolved oxygen, are separated from the feed water. Removal of the oxygen is necessary in order to prevent corrosion in the piping system.

Any loss of water in the system is made up through unit *9* from which make-up water *MW*, after purification, is fed into



a

Fig. 3. Schematic diagram of a central heat and electric power station:

1—belt conveyors, 2—coal stores, 3—self-dumping railway cars, 4—screening unit, 5—hammer-type crushers, 6—coal hopper, 7—automatic scales, 8—ball-type grinding mill, 9—pulverised coal hopper, 10—burner, 11—boiler, 12—superheater, 13—feed-water tank, 14—turbine, 15—heat exchanger, 16—motor-driven pumps, 17—feed-water heaters (water from left-hand feed-water heater is delivered to deaerator), 18—induced-draught fan, 19—generator.

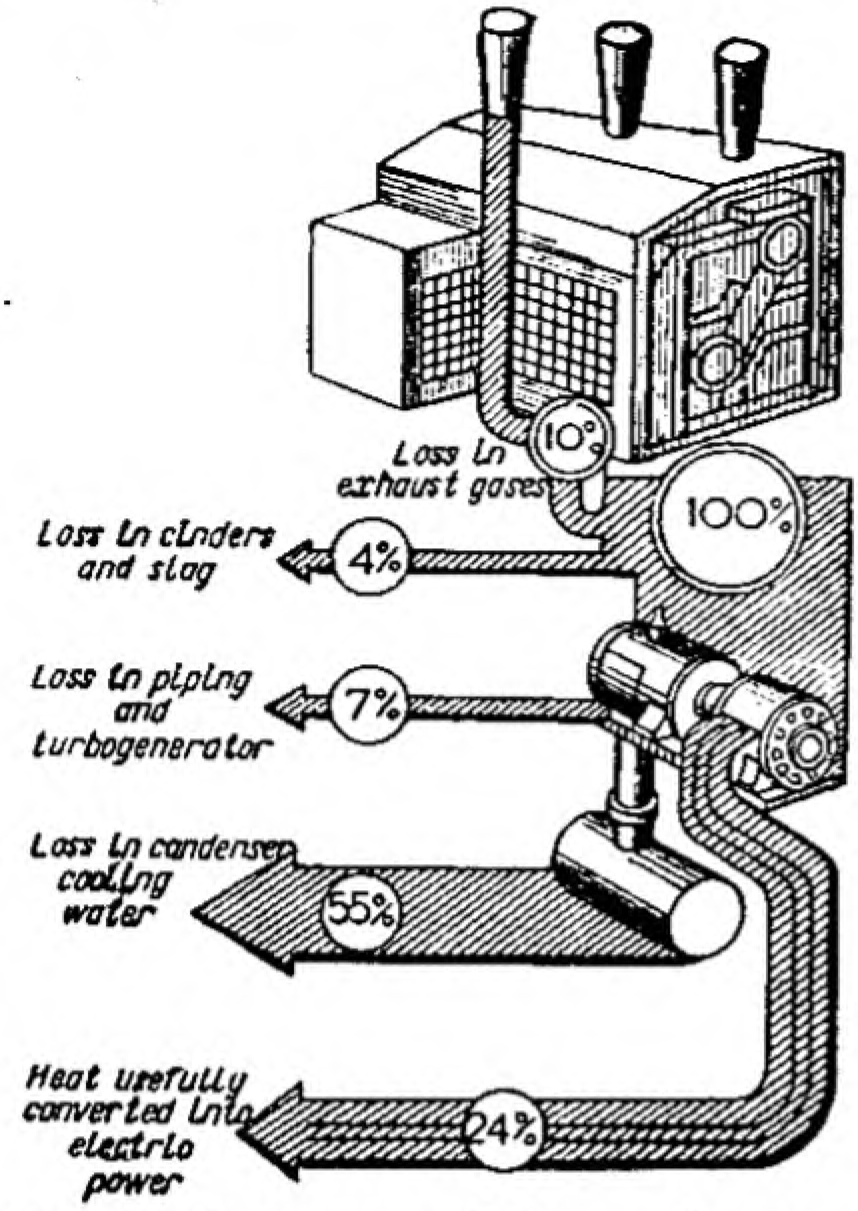


Fig. 2. Heat power balance of a condensing electric power station.

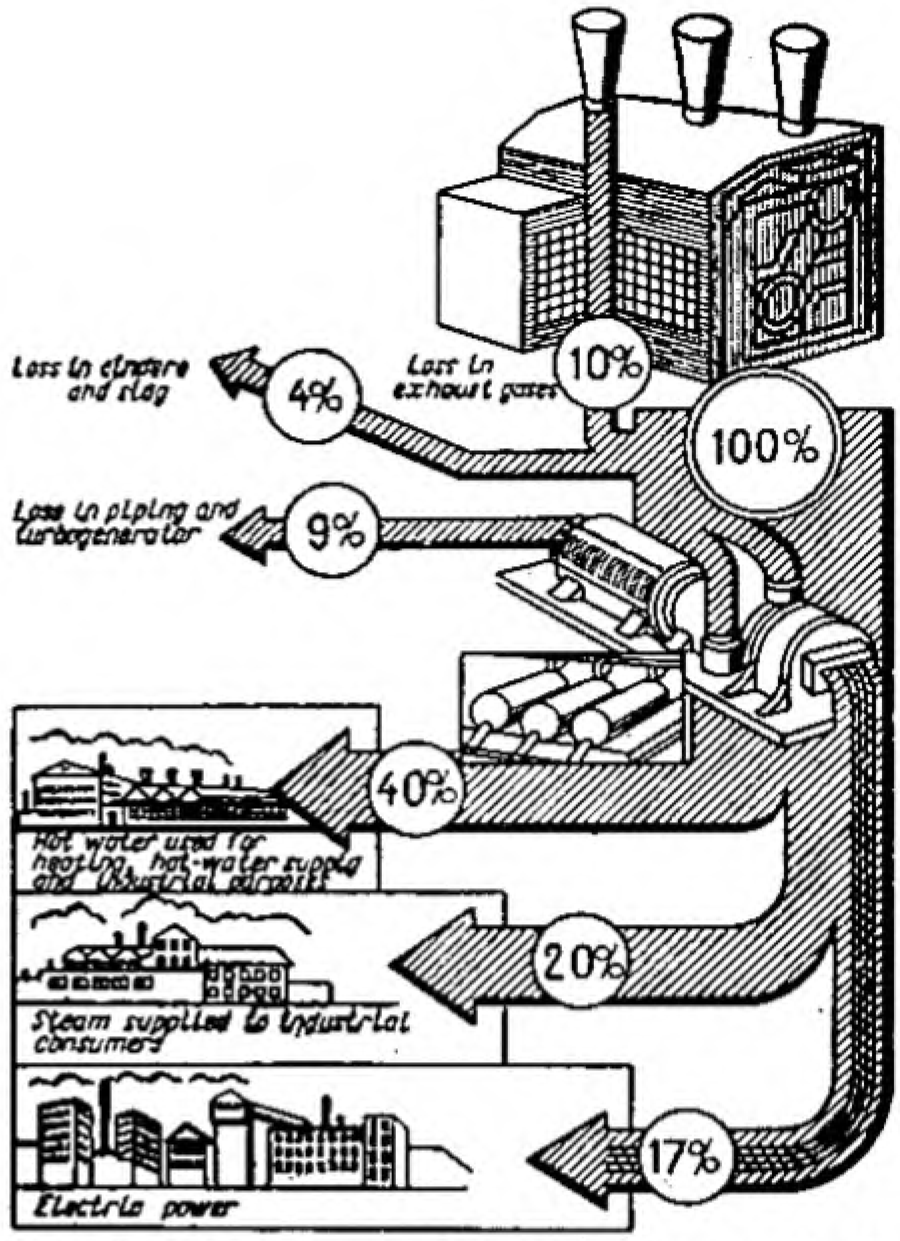


Fig. 4. Heat power balance of a central heat and electric power station.

the deaerator to be then delivered to the boiler.

The electric power *EP* developed in the generator flows to a step-up transformer *12* from which it is fed to the high-voltage buses of the station and is transmitted to the power system through the electric power lines *EPL*.

The efficiency of a condensing station can reach a maximum of 40 per cent and usually does not exceed 24 per cent, as from 60 to 76 per cent of the fuel energy is unproductively lost in the process of producing the electric power.

The heat power balance of a condensing electric power station can be seen in Fig. 2.

Heat and Electric Power Stations

Heat and electric power stations (Fig. 3), which are designed to supply heat power to industrial consumers and hot water to municipal consumers, combine the generation of both heat power and electric power in their production process. Heat power supply is accomplished by extracting live steam from the turbine. This steam is piped directly to industrial consumers and is also passed through a heat exchanger *15* to heat the water which is circulated through the heat exchanger and in the heating mains system by heat-mains water pump *16*.

The efficiency of central heat and electric power stations producing these two forms of power reaches values of 70 per cent and higher. The heat power balance of a central heat and electric power station is shown in Fig. 4.

Atomic Electric Power Stations

An atomic electric power station (Fig. 5) differs from a condensing and a heat and electric power station in that the boiler unit is replaced by an atomic reactor *1* and a steam generator *6*. The atomic reactor is the source of energy obtained in the form of heat as a result of the nuclear chain reaction causing splitting of the uranium nuclei charge. This heat serves to raise the temperature of water passed along fuel-element tubes *11*.

Heated to a temperature up to 300° C, the water is passed through the steam generator where it heats the water circulated from the working circuit to convert it into steam.

From the steam generator, the steam is piped to steam turbine *7* to make it rotate. The turbine, in turn, drives generator *8* to develop electric power which is fed to the distribution switchgear buses of the station and then into the power system to supply the consumers.

Active zone *2* in the reactor is made of graphite. The intensity of the reaction and, consequently, the rate at which energy is liberated in the reactor is controlled by control rod *4*, raised and lowered by electric motor *3*.

Condenser *9* serves to cool the spent steam. The condensate from the condenser is returned to the steam generator by pump *10*.

The massive concrete shield *5* built around the reactor is provided to protect the operating personnel from radioactive radiations.

An approximate heat power balance showing the distribution of energy flow in an atomic electric power station is given in Fig. 6.

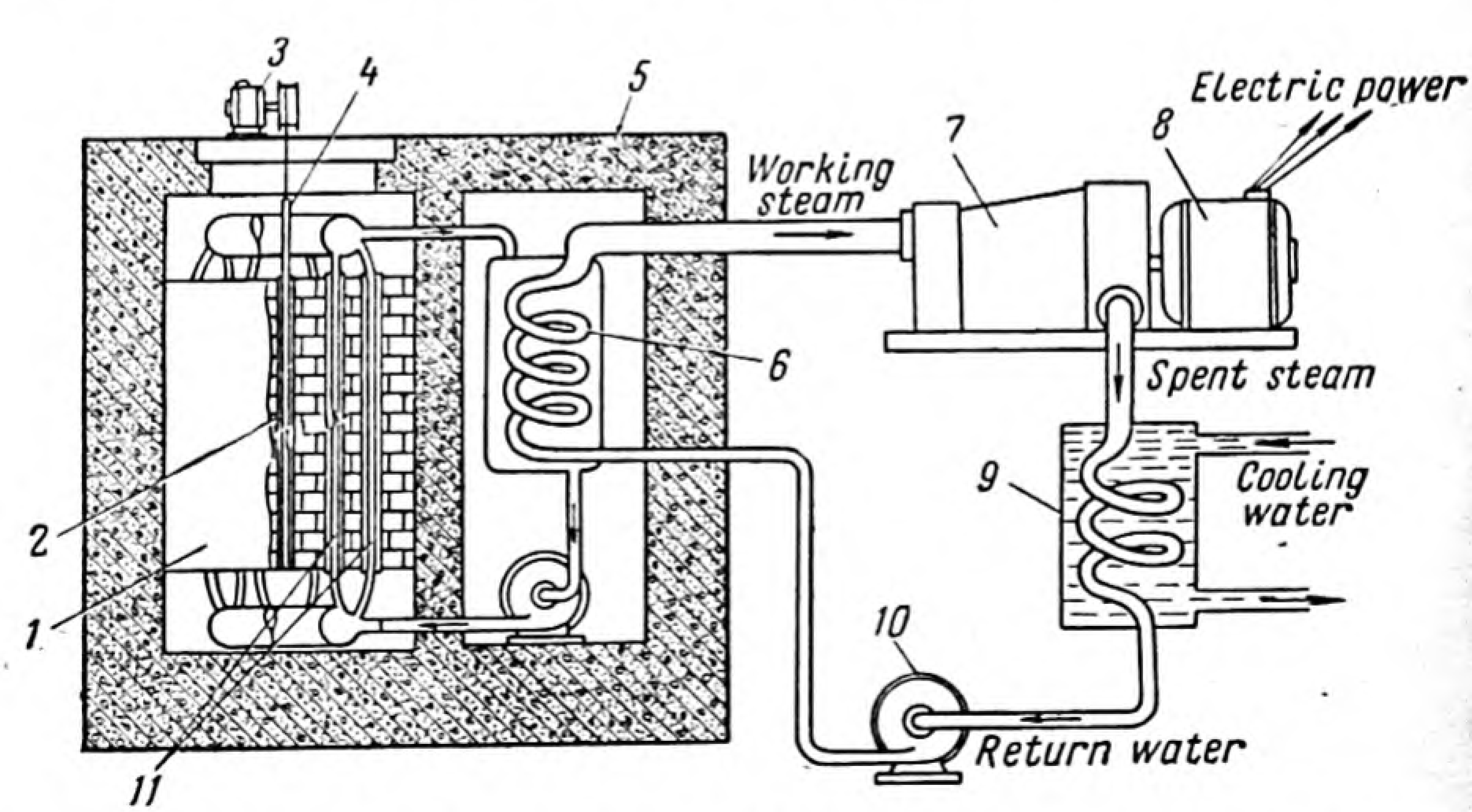


Fig. 5. Simplified diagrammatic scheme of power generation process in an atomic electric power station.

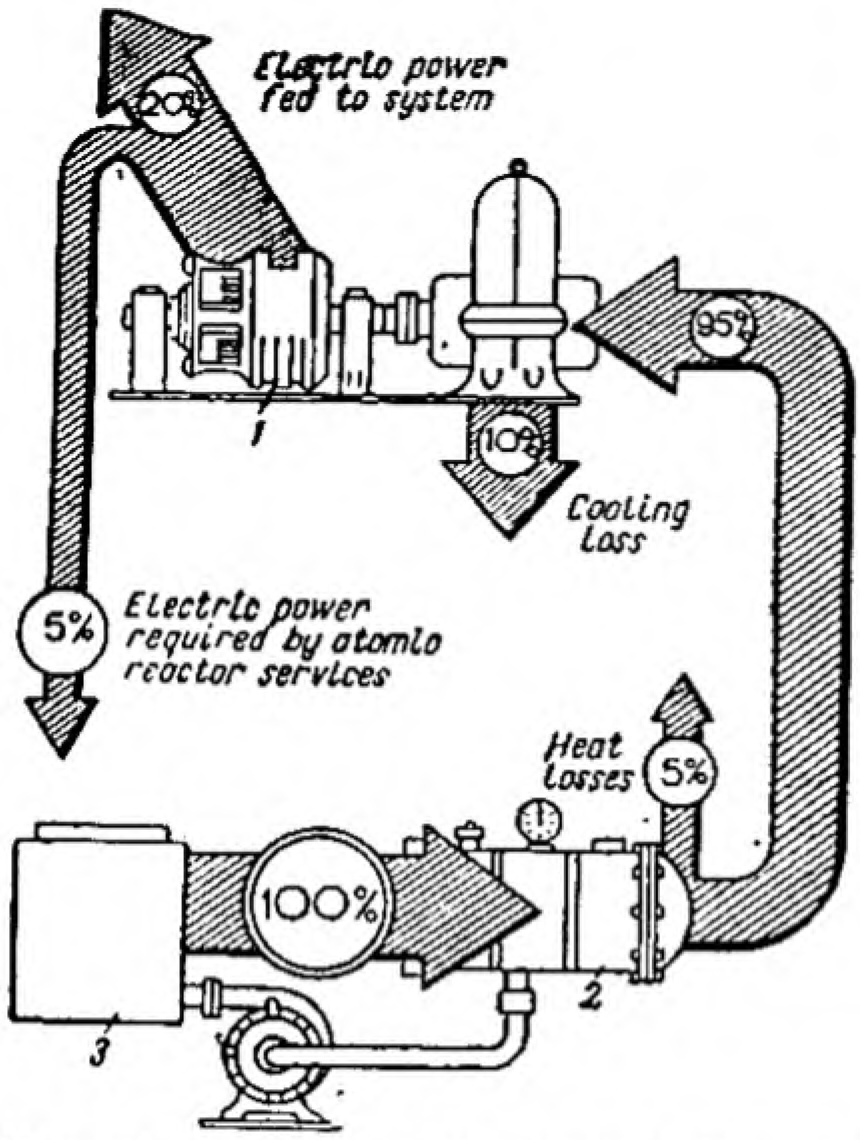


Fig. 6. Approximate distribution of energy flow in an atomic electric power station:

1—turbogenerator, 2—steam generator, 3—atomic reactor.

Note: Loss in condenser cooling water not shown to simplify drawing.

3. Hydroelectric Power Stations

Hydroelectric power stations are built on rivers in places where the rate of water flow and the water head can produce the greatest amount of power.

The process by which power is generated in hydroelectric power stations is not complicated. The water retained behind a dam placed across the river is led, by means of an intake tunnel or penstock, into the spiral casing of a water turbine. From the casing the water enters the turbine runner which rotates the hydrogenerator coupled to the turbine. After performing the mechanical work of turning the turbine runner, the water freely flows out through a tail-race tunnel at the downstream level of the river (below the dam). Hydroelectric power station capacity depends upon the difference in water level created by the dam, i. e., upon the value of the water head and upon the daily flow from the upper reaches of the river, which, as is known, widely fluctuates according to the season of the year. Because of this, water is stored during periods of flood in the reservoirs created by the dam built across the river.

A hydroelectric power station or scheme consists of a series of engineering works of which the main are: a dam (consisting of a spillway for discharging excess water to the downstream side and the dam proper), the powerhouse or power station structure, and locks for passage of river boats.

When large capacity hydroelectric power stations are projected and built, due consideration is given to the need for improving river navigation and for creating facilities for soil watering and irrigation. Due to this, powerful hydroelectric power stations are usually found at large distances from electric power consumers.

Notwithstanding a number of important advantages possessed by hydroelectric power stations over thermal electric power stations (greater efficiency, no need to pay for fuel transportation, extremely small staff of operating personnel), great attention at the present stage of development of power generat-

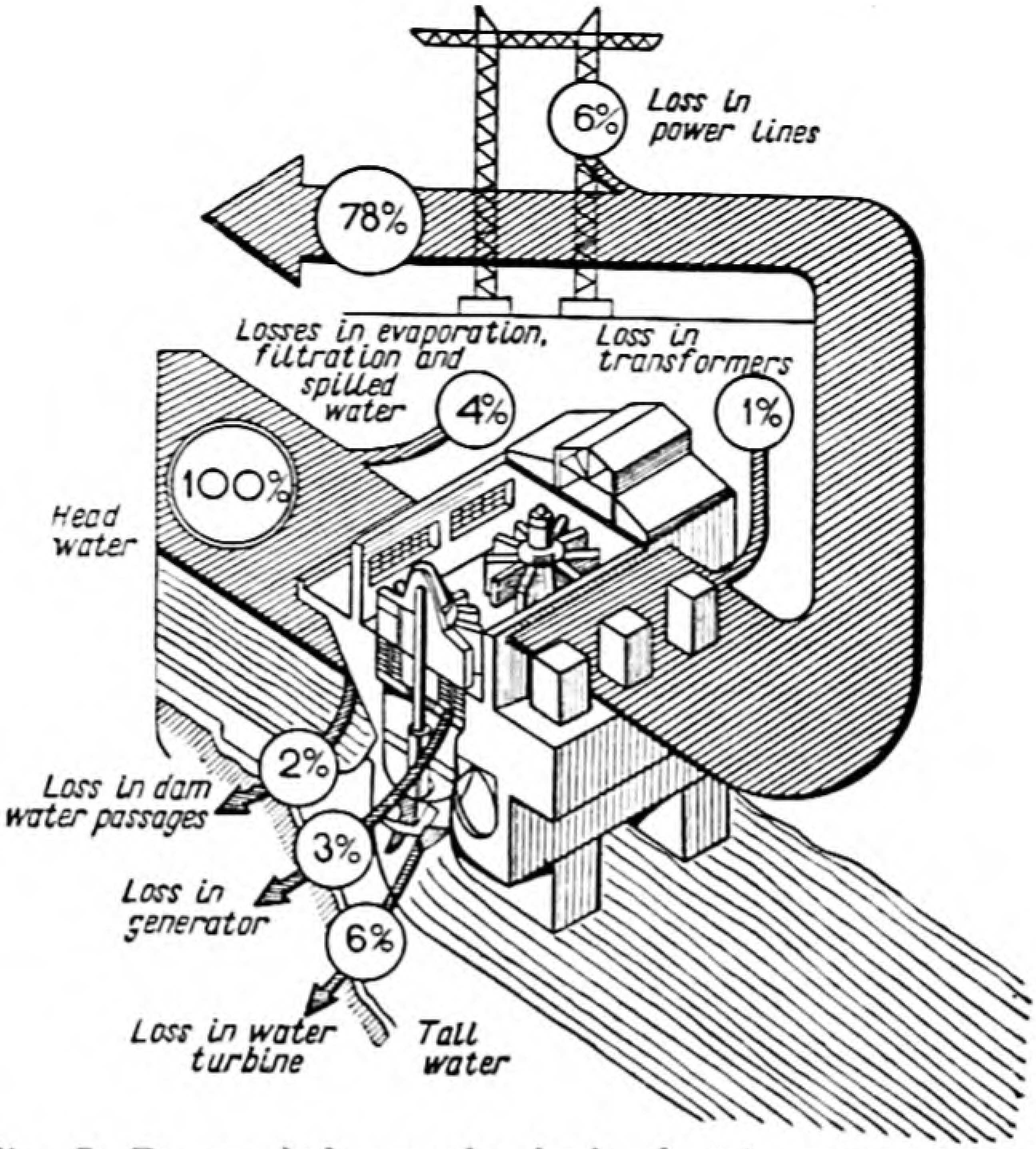


Fig. 7. Energy balance of a hydroelectric power station.

ing capacities is being devoted in the Soviet Union to the building of thermal electric power stations. This is explained primarily by the fact that hydroelectric power stations require a large capital investment and their construction takes a long time to complete. For an energy flow balance of a hydroelectric power station see Fig. 7.

4. *Standard Nominal (Rated) Voltages*

Electric power is generated, distributed and consumed at definite standard values of working voltage called *nominal* or *rated* voltages.

The rated voltage of an electric machine, apparatus, transformer or instrument is established in the U.S.S.R. by All-Union State Standards and is indicated on its rating plate or stamp. This is common practice everywhere.

A distinction is observed in the voltage rating of power consumer equipment and generators of electric power.

For three-phase a-c systems, used very widely in the U.S.S.R., the following standard voltage ratings have been established (for electric power consumer equipment): 127; 220; 380; 500; 3,000; 6,000; 10,000; 35,000; 110,000; 220,000 and 400,000 volts.

Electric lighting circuits are installed as four-wire systems

of 220/127 and 380/220 volts (three phases and the neutral conductor from the earthed neutral point of the transformer). In such systems the lamps are connected across the phase voltage, i.e., respectively, to either 127 volts or 220 volts. Electric motors are connected to the line voltages, 220 or 380 volts.

High-power electric motors used in special installations are manufactured for voltages of 3, 6 and 10 kv. These are the rated voltages generally used for power distribution within industrial works and for urban distribution systems.

Voltages of 35 kv and higher are used mainly for transmitting electric power over large distances.

For three-phase generators and the secondary windings of power transformers, the following voltage ratings have been established: 133; 230; 400; 525; 3,150; 6,300; 10,500; 13,800*; 15,750*; 18,000*; 38,500; 121,000; 242,000; 420,000 volts**.

The voltage ratings of generators and the secondary windings of power transformers are from 5 to 10 per cent higher than the rated voltages of electric power consumer equipment and its associated circuits.

This difference of 5 to 10 per cent in voltage is necessary to compensate for the unavoidable voltage drops in the electric circuits leading from the generators (or transformers) to the power consumers.

5. *Typical Characteristics of Power Consumers*

The main typical characteristics of electric power consumers are the *connected (total) load capacity* of all their electric power receiving apparatus and their *actual load operating conditions*.

Connected load capacity is the term used for the sum of the power ratings of all the electric power receiving apparatus installed on the premises of any given consumer.

By the load is understood the degree to which a consumer uses the connected load capacity.

Changes in the load of a consumer with time are conveniently represented in the form of load curves plotted on rectangular-coordinate graphs.

Fig. 8 represents by way of example the winter and summer daily load (active-power) curves of a group of electric power consumers.

Depending upon how the loading of the various units of consumer equipment varies during the hours of the day, changes will appear in the load curve. Thus, the daily load curve of electric lighting circuits acquires a very irregular shape. Much more power is consumed during the hours of the evening than during the hours of the day, night or early morning.

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* Voltages only for high-power generators and primary windings of special power transformers.

** The last four voltages are for the secondary windings of power transformers.

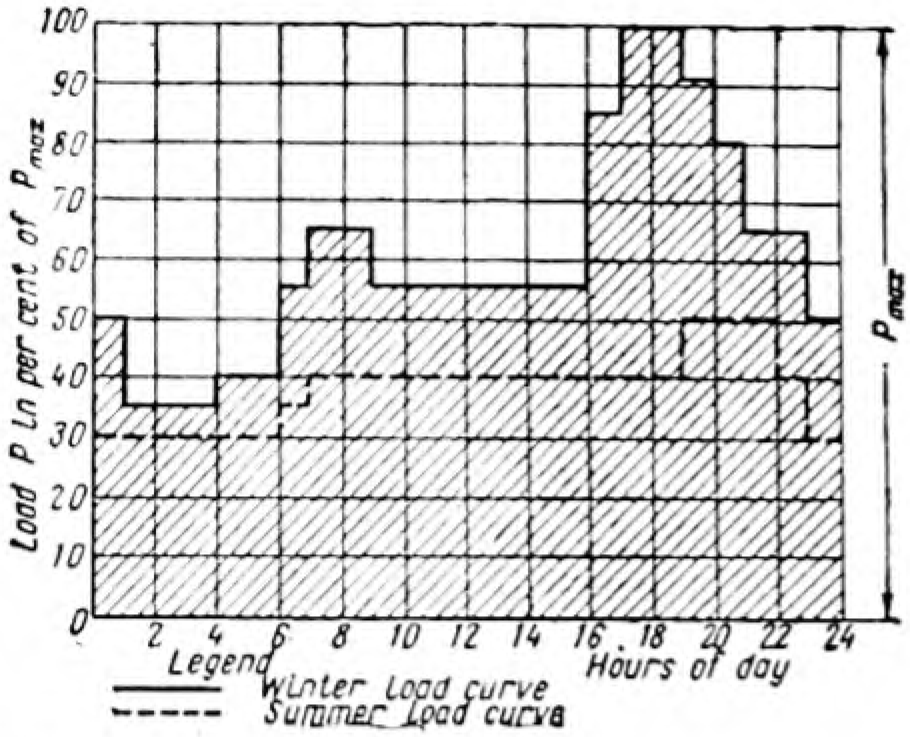


Fig. 8. Winter and summer daily active-power load curves of a group of power consumers.

The largest load which a consumer can have is called the *maximum load* or *demand* (P_{max}). The maximum load is always less than the connected load of the power consuming apparatus installed in the premises because all the units never operate simultaneously and are never fully loaded.

In the majority of cases all the lighting units in a building are not switched on at any one time in all the rooms. In any industrial undertaking all the electric motors usually do not run at the same time because some of the production units may be stopped for adjustment or repair; many of the mechanisms operate intermittently (cranes, welding sets, etc.).

Nonsimultaneity of operation and loading of electric power consumer equipment below its power rating is taken account of by a *demand factor* ($k_{d.f.}$). Indoor lighting circuits have a demand factor of 0.4 to 0.8, while industrial power installations have demand factors ranging from 0.2 to 0.7.

The maximum load P_{max} of a consumer is determined by the formula

$$P_{max} = k_{d.f.} P_c$$

where P_c is connected load capacity of the power consuming equipment.

6. Organisation of Power Supply

The supply of electric power to consumers is most easily illustrated by examination of separate definite main electrical connection arrangements. One of the simplest examples is the scheme for supply of electric power to consumers from a generating plant having a working voltage below 1,000 volts (Fig. 9).

Its circuit connections show that the electric power developed by the generators is fed into the main bus-bars of the generating station and from them into the distribution circuits.

In the above circuit line *L-1* only feeds lighting installations, line *L-3* serves to supply electric motors, and line *L-4* feeds both kinds of loads simultaneously—combined loads.

Lines *L-2* and *L-5* also serve to supply lighting and power installations, but do not show how the loads are distributed in order to simplify the diagram in Fig. 9.

Fig. 10 shows the main circuit connections for consumer supply from a power station operating

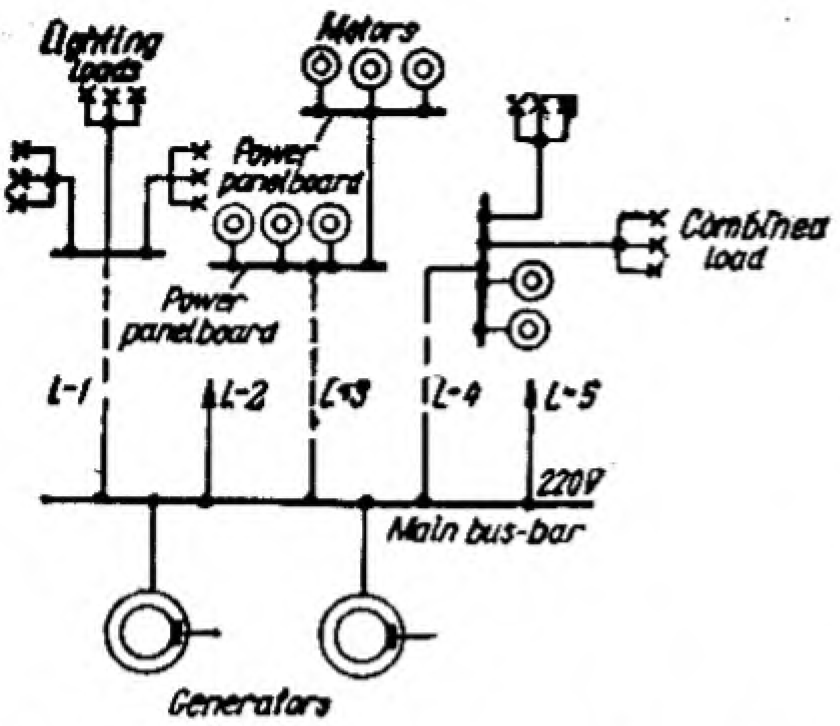


Fig. 9. Circuit connections for supply of consumers from an electric power plant operated at a voltage up to 1,000 v.

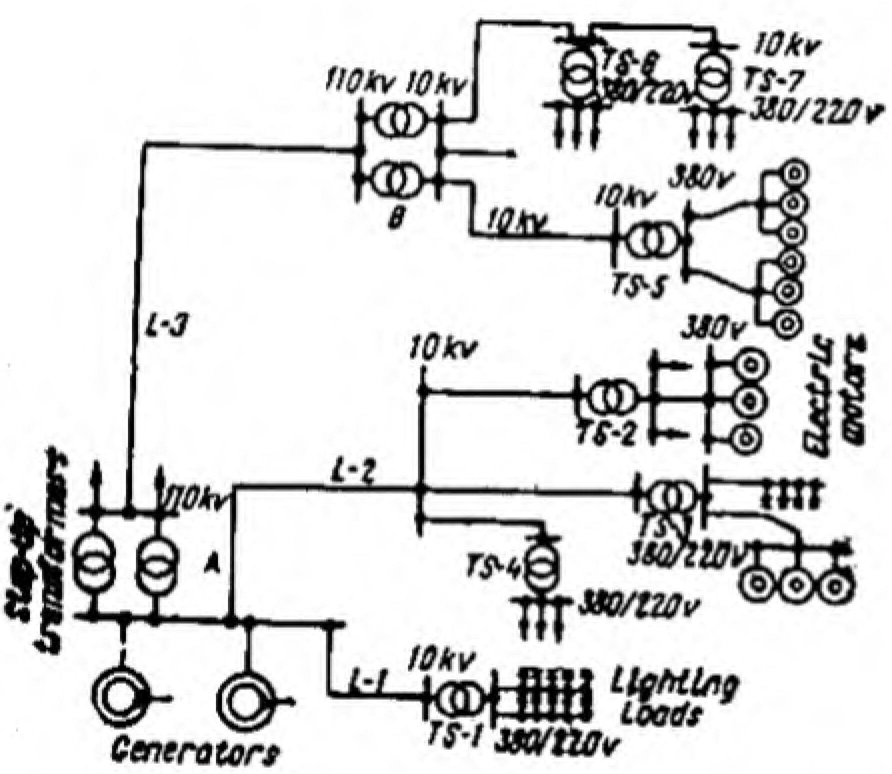


Fig. 10. Circuit connections for supply of consumers from an electric power station operated at a voltage greater than 1,000 v.

at a working voltage greater than 1,000 volts. Here the main circuit connections show that consumers at short distances from the power station, through lines *L-1* and *L-2*, receive power supply at a voltage of 10 kv taken directly off the station bus-bars. At transformer substations *TS-1*, *TS-2*, *TS-3* and *TS-4* the 10-kv voltage is stepped down to 380 volts three-wire or 380/220 volts four-wire, i. e., to the rated voltage at which the consumer equipment is designed to operate.

Consumers located at large distances from the station are supplied at a stepped-up voltage, 110 kv, for transmission over line *L-3*. The necessity for stepping up the voltage, as is known, is due to the fact that the higher the voltage the smaller the current required. Hence, the smaller the cross-sectional area of the conductors and the less the cost of the line.

At substation *A* the voltage is raised by step-up transformers.

At the end of the line, at substation *B*, the voltage is stepped down to 10 kv for supply of substations *TS-5*, *TS-6* and *TS-7* which further lower the voltage to 380 volts three-wire or 380/220 volts four-wire.

The most modern system by which electric power is supplied to consumers is to provide power from several separate stations operated in parallel. The aggregate of such power stations, power line networks, substations and central heating pipe mains from the heating and electric power stations, combined into a whole by the same general operating conditions and the uninterrupted process of production and distribution of electric and heat power, is called a *power system* interconnected by a grid.

Power grids serve large territories within which big indus-

trial regions and cities are located. The high-capacity thermal and hydroelectric stations connected to such grids are built on sites near the natural sources of energy, while smaller central heating and electric power stations are placed within industrial districts and heavily populated areas. A general picture of a power grid can be seen in Fig. 11.

Power grids play a very important part in the national economy because the joint operation of a series of electric power stations provides the means whereby their generating units and the natural power resources are used to the best economic advantage and the power losses are reduced in the networks. Supply of consumers from power grid networks likewise ensures both reliable and continuous power supply as it does not depend upon any one power station.

In the U.S.S.R. several large power grids have been set up, among them such as the Central, Urals, Southern, Leningrad and other systems. Today work is continuing on the further combining of system networks into a single power grid of the European part of the U.S.S.R. and a Central Siberian power grid.

All this enormous work is directed towards establishing a unified power grid for the entire country, the practical embodiment of Lenin's idea of total electrification of the Soviet Union.

The part of a power system consisting of the generators, switchgear installations, power networks (substations and electric power lines) and the connected consumer load is called an electric power system.

7. Regulations on Installation and Operation of Electrical Equipment

General

Electrical installations are designed to generate, transform, distribute and/or consume electric power.

Electric power generating installations comprise the generators and the associated auxiliary equipment in the electric power stations.

Electric power transforming and distributing installations consist of substations and electric power lines of various voltage rating.

Consumer installations are the separate power receiving units of equipment and the whole of such equipment on the premises of a consumer.

When erecting and operating electrical installations it must be firmly understood that electric shocks are always a source of great danger to human life and health. Furthermore, any overheating arising in the separate parts of an electrical installation may lead to the appearance of dangerous temperatures and, under definite conditions,

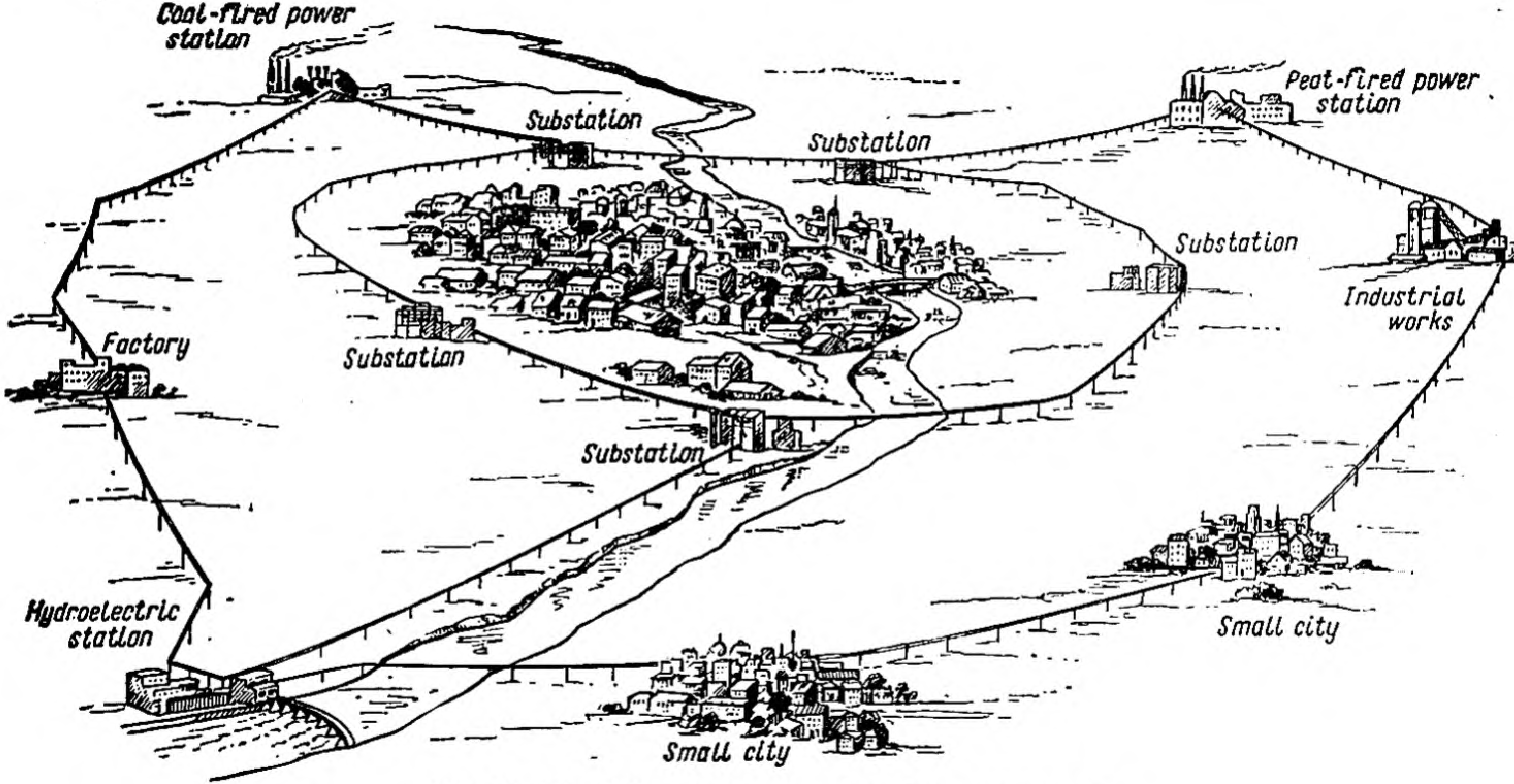


Fig. 11. Pictorial representation of an electric power grid.

result in breakout of fires and even explosions.

Rules for installing and operating electrical equipment serving to preclude any possibility of electric shock hazards and the development of impermissible heating are laid down, in the U.S.S.R., in the "Regulations on Installation of Electrical Equipment" and the "Regulations for Operating Electrical Installations" supplemented by special safety rules. In other countries these Regulations are covered by "Electrical Codes".

In dealing with the installation and operation of electrical circuits and equipment, all considerations will be based on the above-mentioned acting Regulations.

Depending upon operating conditions and difference in design of electrical apparatus, the Regulations on installation divide electrical circuits and equipment into those operated at voltages up to 1,000 volts and those operated at voltages over 1,000 volts.

Besides, installed electrical circuits and equipment in which the voltage between any conductor and earth does not exceed 250 volts are considered to be low-voltage installations; those in which the voltage between any conductor and earth exceeds 250 volts are considered to be high-voltage installations.

In many cases, due to the need to provide higher safety from electric shock hazards, use is made of weak voltages such as 12, 24 and 36 volts a. c.

Groups and Categories of Consumers

Consumers of electric power are subdivided by the Regulations into several groups:

Municipal consumers—primarily those with lighting loads (dwelling houses, business institutions, hospitals, theatres, street lighting systems, etc.).

Industrial consumers—primarily those with power loads (electric motors, electric heating units, electrolysis), industrial works, factories, mines, etc.

Transport-facility consumers—such as electrified railways.

Agricultural consumers.

Electric power when it is received by consumers serves to light the lamps of the lighting systems, operate electric motors, heat furnaces and ovens. All these devices are called electric power receivers.

Not all electric power receivers operate under the same conditions. For example, in one case the electric power receivers may serve to drive units used to supply air to underground mine workings where a large number of men are at work, or serve for production purposes to supply current to very important departments in industrial works in which complicated processing equipment is installed. In another case the receivers drive or serve units installed in departments of auxiliary nature or in unimportant storerooms.

In view of the above, in respect to their requirements for

uninterrupted power supply, power receivers are subdivided into three categories:

First category—power receivers for which the interruption in power supply will result in danger to human life, considerable economic losses, damage to equipment, extensive spoilage of products, interruption of a complicated production process, and stoppage of vital municipal services (water supply systems, transport facilities).

First-category power receivers permit only of a momentary interruption in power supply. Such power receivers must be supplied from two independent power sources, one of which is the stand-by. Transfer of such a consumer to the stand-by power source must take place automatically the instant a power failure occurs in the first source.

Second category—power receivers for which the interruption in power supply will involve a drop in production, standstill of the work staff, and stoppage of machinery and transport facilities.

Interruption in power supply to second-category power receivers is permissible within the limits of time needed for a stand-by source to be switched in without automatic control (by a duty attendant).

Third category—all power receivers which do not fall in the first and second category.

For third-category power receivers a power supply interruption may have a duration of up to 24 hours.

Classification of Premises

The premises in which electrical installations are mounted and operated are characterised by the definite conditions which determine the danger for the installation. Such conditions in premises are: moisture, corrosive vapours and fumes, high temperature, the presence of current-conducting floors (earthen, concrete, metal-covered, etc.), and also the presence of large metal masses (for example, processing equipment).

Under conditions such as those stated above, any person coming in contact with an unprotected current-carrying part even at a comparatively low voltage will be subjected to an electric shock, and in some cases, even to a fatal danger. By reason of such dangers, all premises are classified in the following way.

Dry premises—premises in which the relative humidity does not exceed 60 per cent (living quarters, flats, auditoriums in educational institutions, rooms in business premises, hospitals).

Moist premises—premises in which moisture in small quantities is evaporated for short periods of time and the relative humidity does not exceed 75 per cent (for example, in the kitchens of apartment houses, unheated staircases in dwellings, sheds, unheated storehouses).

Damp premises—premises which usually have a relative humidity over 75 per cent (basements, underground tunnels, kitchens and some of the depart-

ments in food-preparing establishments).

Wet premises—premises in which the relative humidity can reach 100 per cent. In such premises the walls, floors and objects are constantly covered with moisture (for example, bath-houses, laundries, shops of like nature in industrial works).

Hot premises—premises in which the temperature exceeds +30°C.

Dusty premises—premises in which dust is formed in the process of production, settles on the wiring and penetrates into the enclosures of electrical equipment. Such premises are further subdivided into premises with current-conductive dust and premises with nonconductive dust.

Chemically active atmosphere premises—premises in which the conditions of production are such that their atmospheres contain vapours or settle out deposits which have a harmful effect on the electrical equipment.

In addition to the above, premises are divided into three classes according to their degree of danger of shock hazard to human beings.

Heightened shock hazardous premises—premises in which one of the following conditions may exist: moisture or current-conductive dust, current-conductive floors (earthen, reinforced concrete, metal-covered, etc.), high temperature, and also the possibility of a person coming in simultaneous contact with the enclosures of electrical equipment and earthed metalwork in a building, processing machinery, mechanisms, etc.

Highly shock hazardous premises—premises in which one of the following conditions will be found: wetness, a chemically active atmosphere, or the presence of two or more of the heightened shock hazardous conditions.

Premises without heightened shock hazards are those in which none of the heightened or highly shock hazardous conditions exist.

Wiring Classification

The acting Regulations for electrical installation classify wiring as indoor, outdoor and temporary.

Indoor or *interior wiring* comprises all the wires, cords and cables installed within a building together with their fixings and their means of support and protection.

Interior wiring can be installed either unprotected or protected with the use of insulated wire (Chapter II). Such wiring can be *exposed* or *open* (wiring run over the interior surfaces of walls and ceilings, secured to trusses, etc.), or *concealed* (wiring hidden under plaster coatings, in floors, etc.).

Outdoor wiring is installed with bare, protected or insulated wires and with cables which may be supported from or run over the outdoor surfaces of building walls, or strung on poles or other supports which are spaced at distances not greater than 25 metres from each other.

Temporary wiring is installed on construction sites for lighting and other purposes, and intended for a period of service not greater than 5 years.

The methods of installing wiring are identical both for electric lighting and for electric power (motor, heating equipment, electrolysis) installations.

Chapter II

ELECTRICAL INSTALLATIONS RATED FOR VOLTAGES UP TO 500 v

1. Materials and Accessories Used for Wiring Electrical Installations for Voltages up to 500 v

In the installation of the various kinds of wiring use is made of a number of electrical and common construction materials and accessories which may be given the general name of *installation* materials.

Installation materials and accessories, according to their purpose, maybe subdivided into separate typical groups (wires, cords and cables for circuit installation, insulating accessories and materials, control and protective devices, hardware and general construction materials).

Wires, Cords and Cables Used for Wiring Electrical Installations

Wire is the name given to a bare or insulated conductor in the form of one or several strands. Wires serve for the transmission and distribution of electric energy.

Simple insulated wires have their current-carrying conductors covered by an insulating sheath (of rubber, polyvinyl chloride, cotton, etc.), and protected insulated wires have not only an insulating covering but also a protective jacket of metal or some other mechanically strong material.

Cord is the name given to two (less frequently, three and more) insulated flexible conductors twisted together or arranged in a common jacket.

Cable is the name given to one or several insulated multistrand conductors or cores which are enclosed in a continuous hermetic protective sheath of aluminium, lead or polyvinyl chloride (p.v.c.).

The current-conducting copper and aluminium conductors of wires, cords and cables are manufactured in standard sizes having the following cross-sectional areas: 0.5; 0.75; 1; 1.5; 2.5; 4; 6; 10; 16; 25; 35; 50; 70; 95; 120; 150; 185; 240; 300, and further up to 1,000 sq mm.

Conductors are insulated by using rubber and polyvinyl chloride (p.v.c.). The thickness of the insulation and its dielectric quality depend upon the voltage for which the respective insulated conductor is rated.

Rubber insulation is used for the standard voltage ratings of

220, 500 and 3,000 volts; polyvinyl chloride insulation is used for the voltage ratings of 250 and 500 volts.

By the *grade of a wire*, cord or cable, is meant the letter type designation which serves to indicate whether it is a wire, cord or cable, of what materials the conductors and their insulation are made, the degree of flexibility of the conductors, and the presence and construction of the protective coverings. For example, grade АПР (APR) indicates that we have a wire with an aluminium conductor which is rubber-insulated; grade ПРП (PRP) indicates that we have a rubber-insulated copper-conductor wire with a braided-wire metal sheath.

Figures are often added to the grade designation of a wire to indicate the voltage rating, number and size of the conductors. For example, grade ПР-500 (PR-500) is to be decoded as rubber-covered copper-conductor wire rated for 500 volts, while ВРГ 3×2.5 (VRG 3×2.5) is to be decoded as bare p.v.c.-sheathed cable having three rubber-insulated conductors, each 2.5 sq mm in size.

Below we shall examine the construction of the main grades of wires, cords and cables.

Unprotected Insulated Wires. Grade ПР (PR) copper-conductor wire (Fig. 12*a*) is manufactured with rubber insulation rated for voltages of 500 and 3,000 volts, grade АПР (APR) aluminium-conductor rubber-insulated wire—rated for voltages of 220 and 500 volts; these wires have sizes from 0.75 to 400 sq mm.

The above grades of wire, in sizes up to 10 sq mm, are single-strand (or solid) wires; in the larger sizes they are made multi-strand.

Grade ПРГ (PRG) is rubber-insulated flexible copper-conductor wire (Г—meaning flexible) rated for voltages of 500 and 1,000 volts.

Grade ПВ (PV) wire has polyvinyl chloride insulation and is rated for voltages up to 500 volts; it has no braided covering and is manufactured in sizes from 0.75 to 10 sq mm.

Grade ППВ (PPV) (Fig. 12*b*) is a wire of flat construction, has polyvinyl chloride insulation, is rated for voltages up to 500 volts and has no braided-cotton covering. This is a wire of more involved construction and is manufactured as twin-core and three-core wire in sizes up to 4 sq mm with ordinary and light-ray resistant (for exposed wiring) insulation.

Grade ПРТО (PRTO) (Fig. 12*c*) is a multi-core, rubber-insulated type of wire made with a common, impregnated braided-cotton jacket for draw-in installation in conduit pipes and is intended for voltages from 500 to 2,000 volts. This grade is manufactured as single-, two-, three- and four-core wire, the single-core wire being available in sizes from 1 to 500 sq mm; the multi-core wires—in sizes from 1 to 120 sq mm. The fourth core in four-core wires has a cross-sectional area one-half that of the other cores

because it is used only as the neutral conductor.

Grade ПРД (PRD) (Fig. 12*d*) is twisted-pair, braid-covered, rubber-insulated wire for voltages up to 220 volts. It has multi-strand conductors and volts and is available as single-, two-, three- and four-core wire in sizes from 1 to 10 sq mm.

Grade ПРП (PRP) is a multi-core rubber-insulated type of wire with a braided-wire sheath and comprises a grade ПРТО

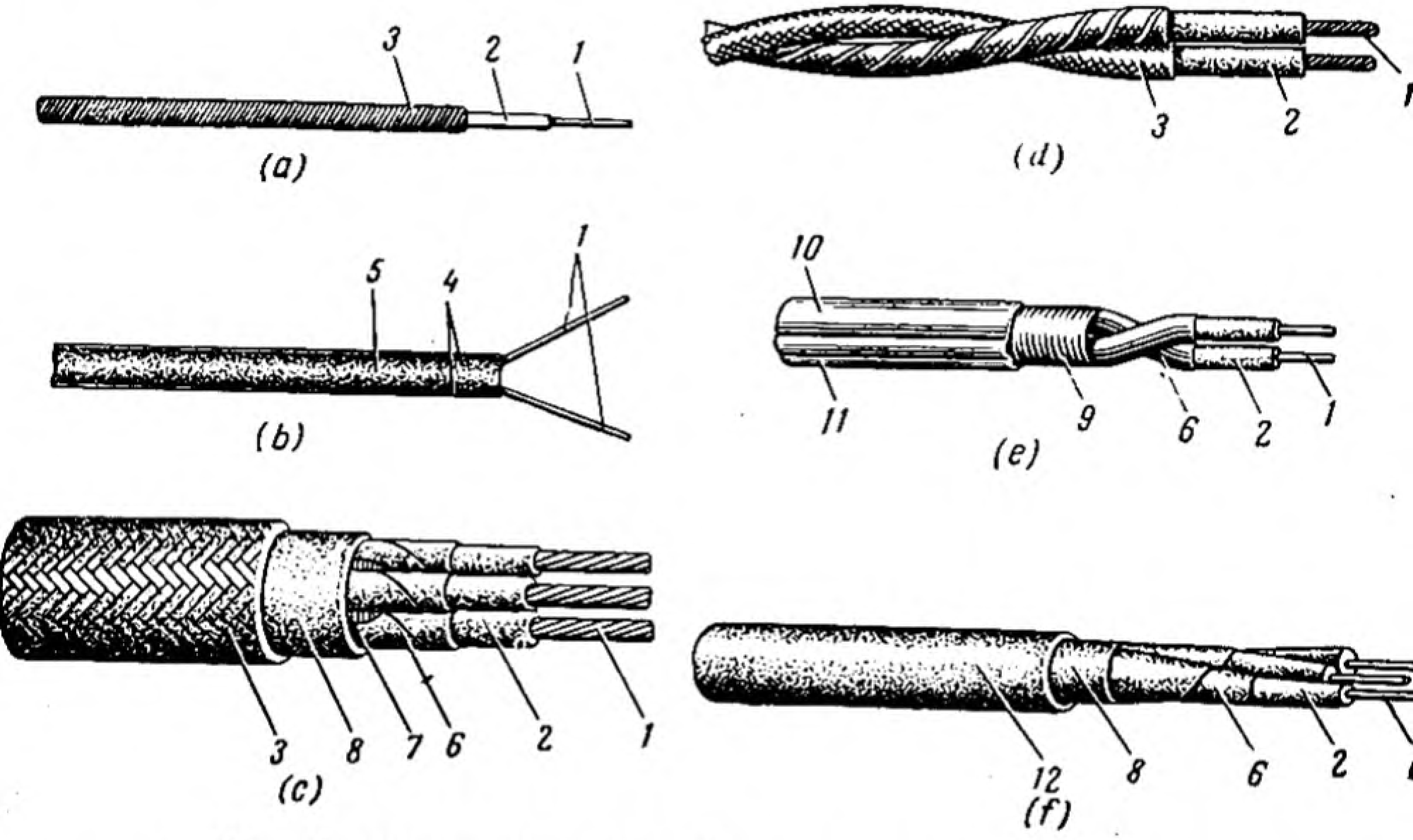


Fig. 12. Construction of insulated wires, cords and cables:
a) grade ПР (PR) wire, *b*) grade ППВ (PPV) wire, *c*) grade ПРТО (PRTO) wire, *d*) grade ПРД (PRD) twisted-pair wire, *e*) grade ТПРФ (TPRF) wire, *f*) grade ВРГ (VRG) p.v.c.-sheathed cable; *1*—copper conductor, *2*—rubber insulation, *3*—impregnated braided-cotton covering, *4*—polyvinyl chloride (p.v.c.) insulation, *5*—p.v.c. bridging film, *6*—rubberised fabric serving (for sizes over 10 sq mm), *7*—jute filling, *8*—common belt serving of rubberised fabric, *9*—common serving of cable paper or fabric, *10*—thin steel jacket, *11*—lock-jointed seam, *12*—hermetic polyvinyl chloride sheath (blue, red, grey).

is available in sizes from 0.75 to 6 sq mm.

Protected Types of Wires. Grade ТПРФ (TPRF) (Fig. 12*e*) is a metal-jacketed, rubber-insulated type of multi-core wire having a thin-steel, seamed (lock-jointed) protective jacket. The joint of the jacket is not hermetic. This wire has insulation designed for voltages up to 500 (PRTO) wire provided with a protective covering braided from thin galvanised-steel wires. This grade of wire is made as single-, two- and three-core wire in a common sheath.

Cords. Grade ШР (ShR) cord is of the same construction as twisted-pair grade ПРД (PRD) wire, differing from it only in that its conductors have greater

flexibility due to the smaller diameter and greater number of strands in each conductor.

Grade ШРПС (ShRPS) is a portable rubber-insulated type of cord with a medium-duty rubber sheath. Differing from it, also available is grade ШРПЛ (ShRPL) cord which has a light-duty rubber sheath.

Grade ШРПС and ШРПЛ cords are used for connecting portable electric power receivers. The first of these cords is designed for protection against moderate mechanical force and injury, and can be used for voltages up to 500 volts. The second (light-duty) grade of cord is designed for use where the mechanical forces are light and can be used for voltages up to 220 volts.

Cables. Grade ВРГ (VRG) (Fig. 12*f*) is a rubber-insulated, polyvinyl-chloride-sheathed type of cable rated for voltages up to 500 volts and is manufactured with a single core, two cores or three cores in sizes from 1 to 240 sq mm. The hermetic plastic sheath of this grade of cable is resistant to acids, bases and oils.

Grade СРГ (SRG), a lead-sheathed, rubber-insulated type of cable, is similar in general construction to grade ВРГ cable.

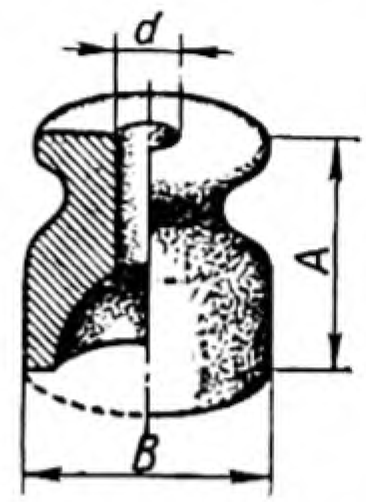
Insulating Accessories and Materials

Among the insulating accessories are: porcelain knobs, insulators, bushings and bent tubes, and semihard rubber and glass tubing.

Porcelain knobs serve as supports for wiring installed in dry and moist premises. Their principal dimensions and general appearance can be seen in Table 1.

Table 1

Porcelain Knobs



Type	Dimensions, mm		
	A	*B*	*d*
РШ-4 (RSh-4)	24	20	6
РП-2.5 (RP-2.5)	25	25	6
РП-6 (RP-6)	31	31	7
РП-16 (RP-16)	35	35	7
РП-35 (RP-35)	38	38	8
РП-70 (RP-70)	42	42	11
РП-120 (RP-120)	50	50	14

Note: Ш (Sh) indicates that the knob is for use in wiring with twisted-pair cord wires such as ПРД (PRD). П (P) indicates that the knob is for wiring with grade ПР (PR) wire. The number in the type designation indicates the maximum size of wire which can be supported by the knob.

Porcelain insulators (of the pin type) are used to support wiring in damp, wet and hot premises, in premises with a chemically active atmosphere, and also in the open air. For the principal dimensions and features of such insulators see Table 2.

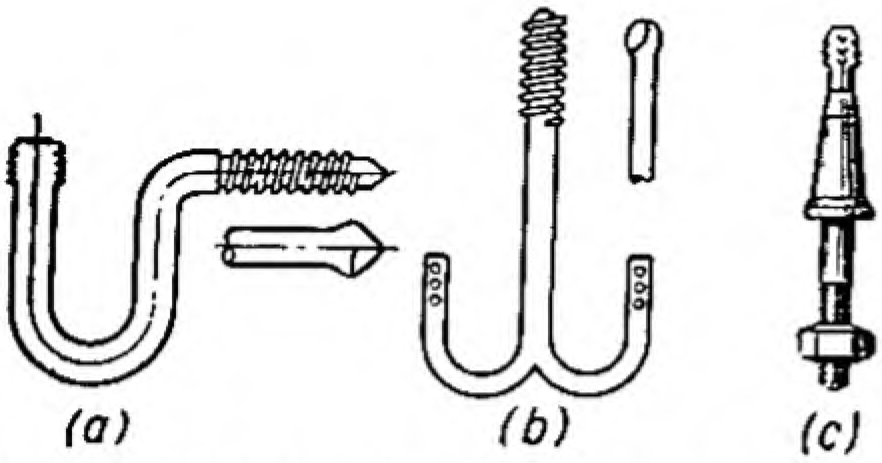


Fig. 13. Fixing hardware for pin insulators:
a—hook (gooseneck), b—two-hook anchor, c—stud.

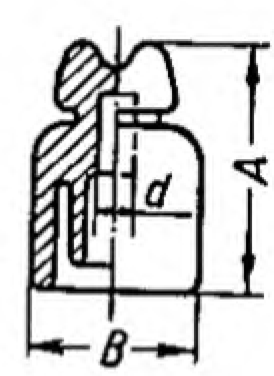
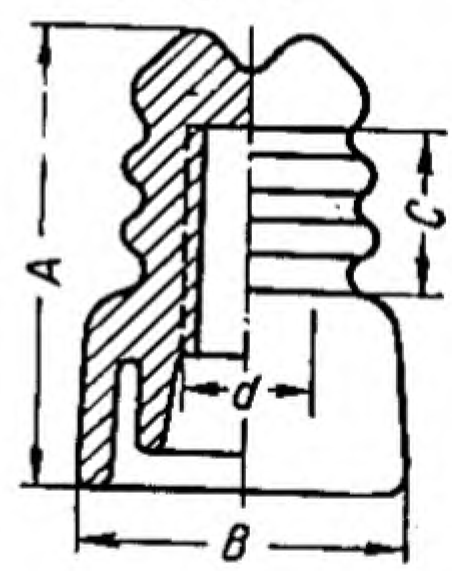
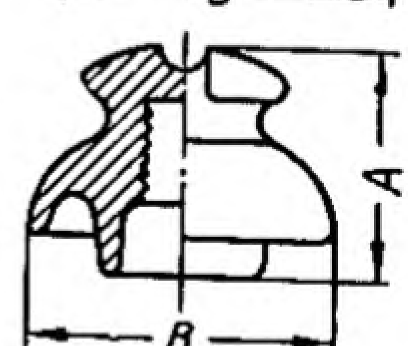
Fixing hardware used for installing pin insulators takes the form of hooks (goosenecks), two-hook anchors, single-hook anchors and studs (Fig. 13).

Hooks (goosenecks) are made in sizes (diameters) of 9.5, 13, 18 and 20 mm. Two-hook and single-hook anchors have sizes of 9.5, 13 and 16 mm. Studs have diameters of 18 and 20 mm.

Insulating tubing and *straight tubes* serve as an additional means of insulating wires in installations where they pass through walls and floor

Table 2

Porcelain Insulators
(pin type)

Type	Dimensions, mm				Sketch
	A	B	C	d	
ШЛН-1 (ShLN-1)	103	101	—	17	
ШЛН-2 (ShLN-2)	83	85	—	17	
ШЛН-3 (ShLN-3)	65	67	—	13	
ШЛН-4 (ShLN-4)	52	58	—	12	
ТФ-2 (TF-2)	112	85	—	20	
ТФ-3 (TF-3)	90	72	—	18	
ТФ-4 (TF-4)	70	58	—	17	
Ш-О-16 (Sh-O-16)	87	61	45	18	
Ш-О-70 (Sh-O-70)	120	80	60	12	
АИК-1 (AIK-1)	103	101	—	—	
АИК-2 (AIK-2)	83	85.5	—	—	
АИК-3 (AIK-3)	65	67	—	—	
АИК-4 (AIK-4)	52	58	—	—	

Note: Letters in insulator type designations denote: Ш (Sh)—pin type; Л (L)—for line use; Н (N)—for outdoor service; О—tee-off; Т—telegraph type; Ф(F)—porcelain; АИК (AIK)—designation of works, a porcelain insulator; figures 1, 2, 3 and 4 are works indices; figures 16 and 70—maximum size of wires.

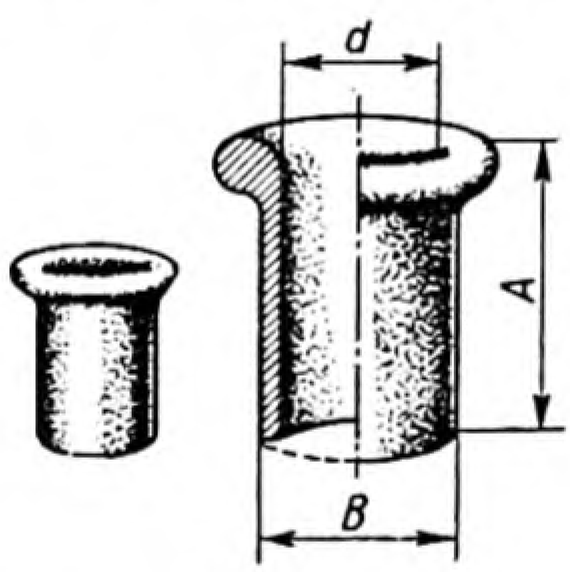
structures, and also where wiring is run concealed under plaster finish coatings.

Semihard rubber tubing is available with inside diameters of 7, 9, 11, 13, 16, 23, 29 and 36 mm, and glass tubes are furnished in the sizes: $^1/_4$", $^1/_2$", $^3/_4$", 1" , $1^1/_2$" and 2".

Porcelain bushings and *bent tubes* are used as a means of additional insulation for wires where they come out of a wall surface and as a means for protecting insulating tubing from being torn (other cases where bushings find use will be given in the second part of this book). The types and dimensions of porcelain bushings and bent tubes are shown in Tables 3 and 4.

Table 3

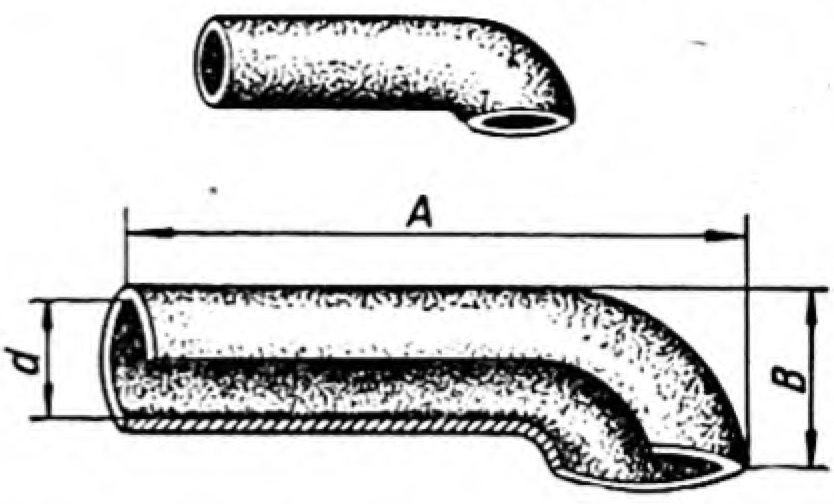
Porcelain Bushings



Type	Dimensions, mm		
	A	B	d
ВФД-5 (VFD-5)	25	17	12
ВФД-7 (VFD-7)	25	19	14
ВФД-9 (VFD-9)	30	24	16
ВФД-11 (VFD-11) . . .	35	27	20
ВФД-13 (VFD-13) . . .	40	30	23
ВФД-16 (VFD-16) . . .	40	33	26
ВФД-25 (VFD-25) . . .	50	42	35
ВФД-29 (VFD-29) . . .	50	50	42
ВФД-36 (VFD-36) . . .	50	60	50

Table 4

Porcelain Bent Tubes



Type	Dimensions, mm		
	A	B	d
B-2 (V-2)	75	19	10
B-6 (V-6)	90	20	12
B-10 (V-10)	102	23	15
B-16 (V-16)	110	24	16
B-25 (V-25)	113	27	18
B-35 (V-35)	120	31	20
B-70 (V-70)	130	36	23
B-95 (V-95)	140	43	30

As insulating underlinings and padding for wiring, use is made of electrical-grade pressboard 1 to 2 mm thick. Places where electric conductors are spliced or connected and where wires are secured to their supports are protected with a wrapping of rubberised insulating tape having a width of 10, 15, 20 or 50 mm. In carrying out the termination of cables, use is made of cotton, tarred fabric and p.v.c. insulating tapes, bitumen and oil-rosin filling compounds, and also of electrical-grade synthetie varnishes such as bakelite, polyvinyl-chloride resin, etc.

Wiring Installation Protective and Switching Devices

Various kinds of switches are employed to connect permanently installed electrical equipment to power supply or to switch it off. In lighting circuits it is usual to install single-pole lighting switches which break the circuit in only one of the supply conductors and leave the lighting fittings under voltage because connection to supply is maintained unbroken by the second conductor.

The main parts of a lighting switch are the insulating base (of porcelain or moulded plastic), fixed contacts with terminals for connection of the conductors, moving contacts, an operating handle and a cover.

According to their principle of operation, lighting switches may be distinguished as rotary types having sliding moving contacts which are arranged on a drum, as lever-operated types with wedge contacts and as push-button types with butt contacts.

As to design, lighting switches are available for surface mounting in premises with normal atmospheres, for flush mounting in concealed-wiring installations buried under plaster, and for mounting in wet premises where the switches have a hermetic case.

Special types of single-pole lighting switches are made for multi-way switching. They have an involved contact system and are used, for example, for chandelier switching.

Another form of multi-way switches is the kind designed to control a given group of lighting units from different places.

In addition to the usual single-pole switches there exist two-pole lighting switches installed in highly shock hazardous premises. No potential can remain on the conductors of a circuit disconnected by such a switch. This removes any danger of electric shock and makes it completely safe to carry out repairs and maintenance work, replace lamps, etc.

Portable electric equipment and appliances such as electrified hand tools, domestic appliances, portable and table lamps are connected to supply by means of plug and socket arrangements.

The ordinary plug and socket (Fig. 14) consists of two parts: the socket to which the supply circuit is connected and the plug to which the portable device is connected through its flexible cord.

For lighting installations, two-pole plug and sockets are used. The main parts of a two-pole plug and socket (see Fig. 14) are: porcelain or moulded-plastic base *1*, two socket contacts *2*, clip terminals *3* for the fuse-link wire and terminal contacts under the insulating base for connection of the supply-circuit conductors (not shown in Fig. 14).

Plug sockets are available for surface mounting in premises with a normal atmosphere, for flush mounting and for mounting in damp premises, for which they are of hermetic design.

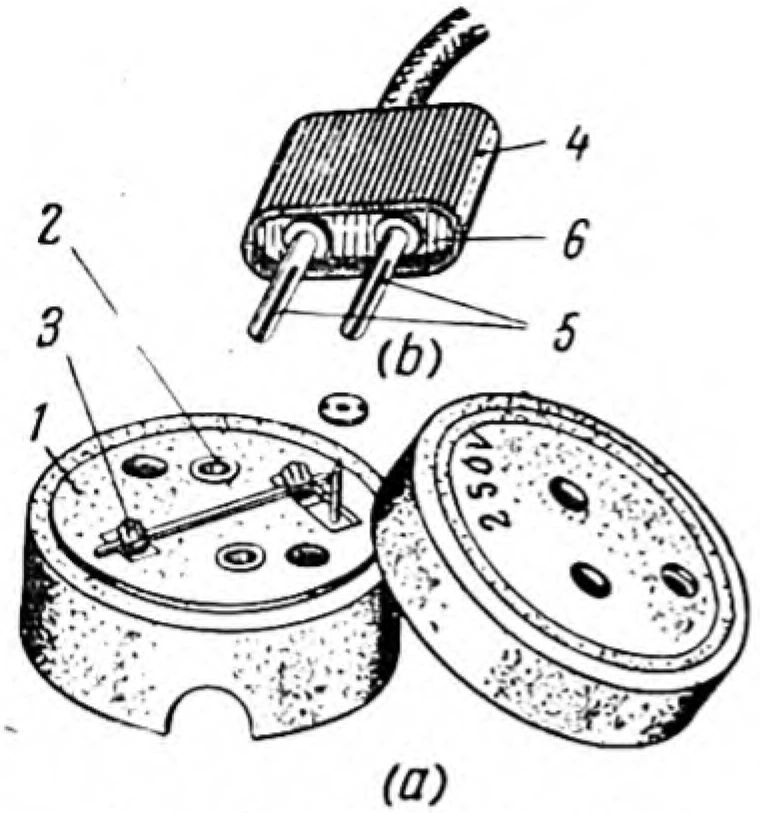


Fig. 14. Plug and socket:
a—socket parts, b—plug.

A socket plug (Fig. 14b) consists of an insulating body 4 carrying embedded screws, two springy-end contact pins 5 for plugging into the socket openings and an insulating cover strip 6 to seal off the open space where the conductors are attached to the contact pins. A plug and socket of the above type is rated for 6 amperes.

Plug and sockets for portable electric equipment which require earthing of their frames are provided with a special contact for connection of the earthing conductor.

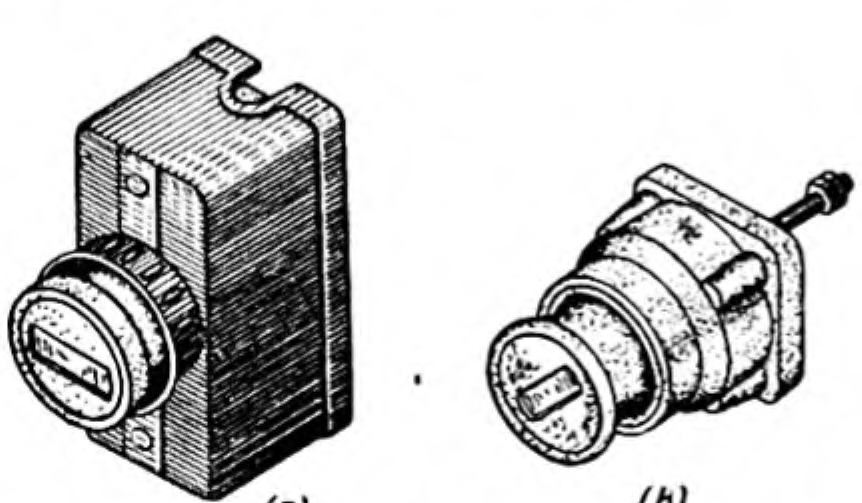


Fig. 15. Single-pole screw-plug fuse unit.
a—rectangular base, b—square base.

In addition to plug and sockets of two-pole construction, use is also made of three-pole plug and sockets.

Among the various protective devices used in wiring installations are the fuses. They may be of the plug or tubular type.

The most widely used of the plug type fuses is the single-pole screw-plug fuse unit which has a rectangular or square base (Figs 15 and 16).

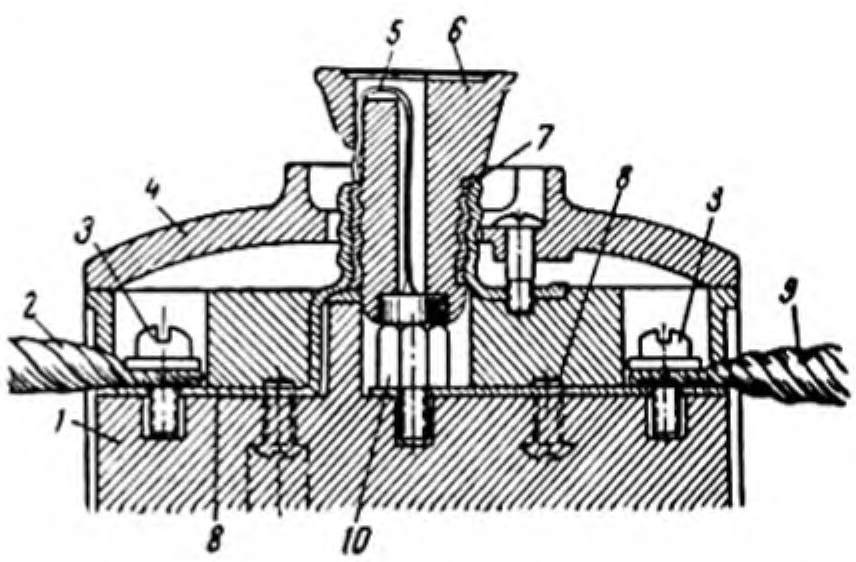


Fig. 16. Arrangement of parts in a single-pole screw-plug fuse unit:
1—insulating base, 2—outgoing conductor, 3—terminal screws, 4—cover, 5—fusible element, 6—porcelain plug body, 7—screw-thread shells, 8—contact plate, 9—incoming conductor, 10—contact screw.

Such a fuse unit (Fig. 16) has two main parts: a base containing a screw socket shell and the screw plug containing the fusible element. When a current due to a short circuit or a current of excessive value flows through the element in the plug, the link melts ("blows out") to break the circuit.

Plug fuse units are made in three sizes:

1) minimum (small), having a screw-thread diameter of 14 mm (Ц-14 or E-14) and rated for 250 v, 10 a; they are rarely used today;

2) normal, having a screw-thread diameter of 27 mm (Ц-27 or E-27) and rated for voltages up to 500 v and currents up to 20 a;

3) maximum (large), having a screw-thread diameter of 40 mm (Ц-40 or E-40) and rated for voltages up to 500 v and currents up to 60 a.

Fig. 17. Screw-plug circuit breaker:

1 — switch-in (reset) button, 2 — trip button.

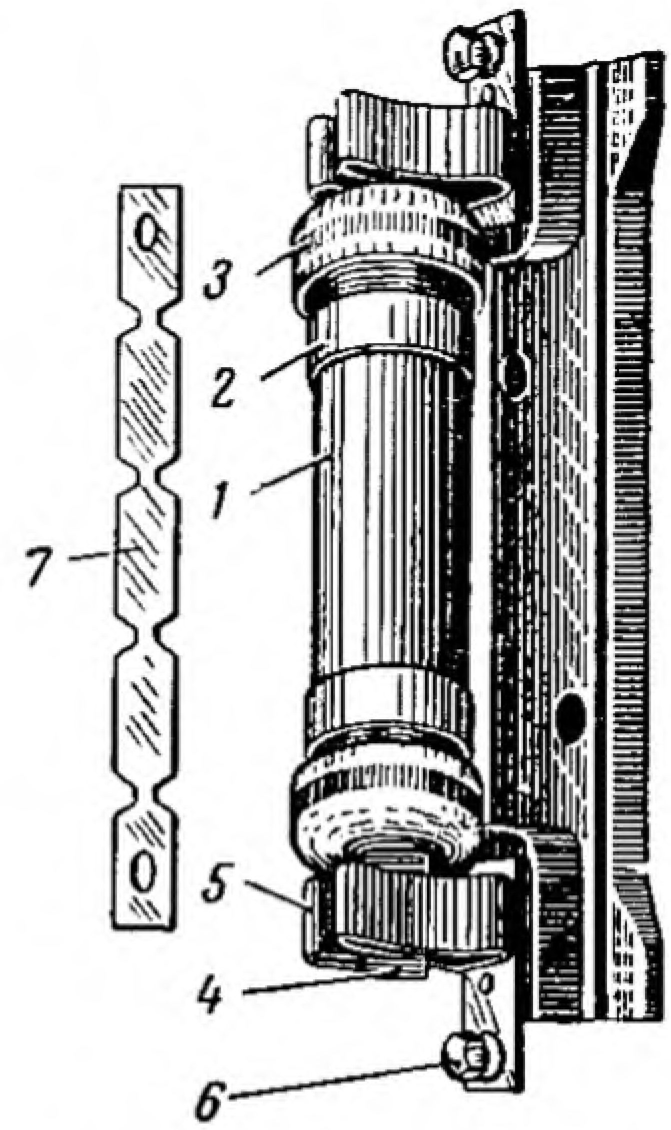


Fig. 18. Type ПР (PR) renewable tubular fuse:

1 — fibre tube, 2—threaded brass ferrule, 3—screw-on end cap, 4—contact knife blade, 5—contact clip, 6—contact terminal for connection of conductors, 7—renewable fuse link.

Screw plugs for normal-size fuse units are made with fuse elements rated for currents of 6, 10, 15 and 20 a. The screw plug of 6-a rating has the greatest height and requires a contact screw of smallest height in the base. The greater the current rating of the screw plug, the smaller its height and the higher the contact screw to be used in the base. A contact screw corresponding in rating to the greatest permissible current to be allowed in the circuit being protected should be screwed into the fuse base. This will ensure reliable protection in that when a plug of excessive current rating is screwed in, it will be unable to come in contact with the inserted proper-rated screw and thus complete the circuit. No current of impermissible value will then be able to flow.

In addition to fusible-element screw plugs, also in use today are automatic screw-plug circuit breakers (Fig. 17). Such devices, often being tripped by an overload or short-circuit current, may be switched in again by pushing reset button *1*. The circuit being protected can be

opened by pushing trip button 2.

Besides plug fuses, wide use is made of tubular type fuses with fibre or porcelain cases.

One of the fibre-case forms is the type ПР (PR) fuse—meaning renewable-element fuse (Fig. 18). This type of fuse is available in voltage ratings of 220 and 500 volts.

currents reach values close to the current rating.

Type НПР (NPR) tubular fuses—meaning filled, renewable, (Fig. 19) and type НПН (NPN) tubular fuses—meaning filled,

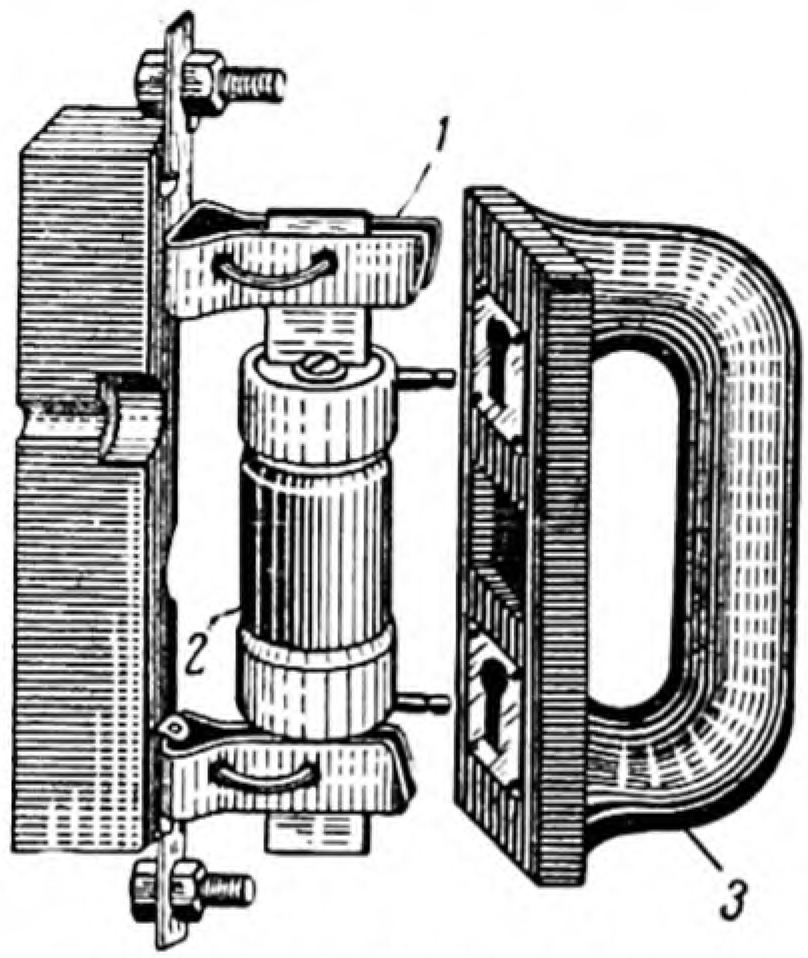


Fig. 19. General view and parts of a type НПР (NPR) renewable quartz-sand-filled fuse:

1—base and terminals, 2—case containing fuse link, 3—handle device used for removing fuse case.

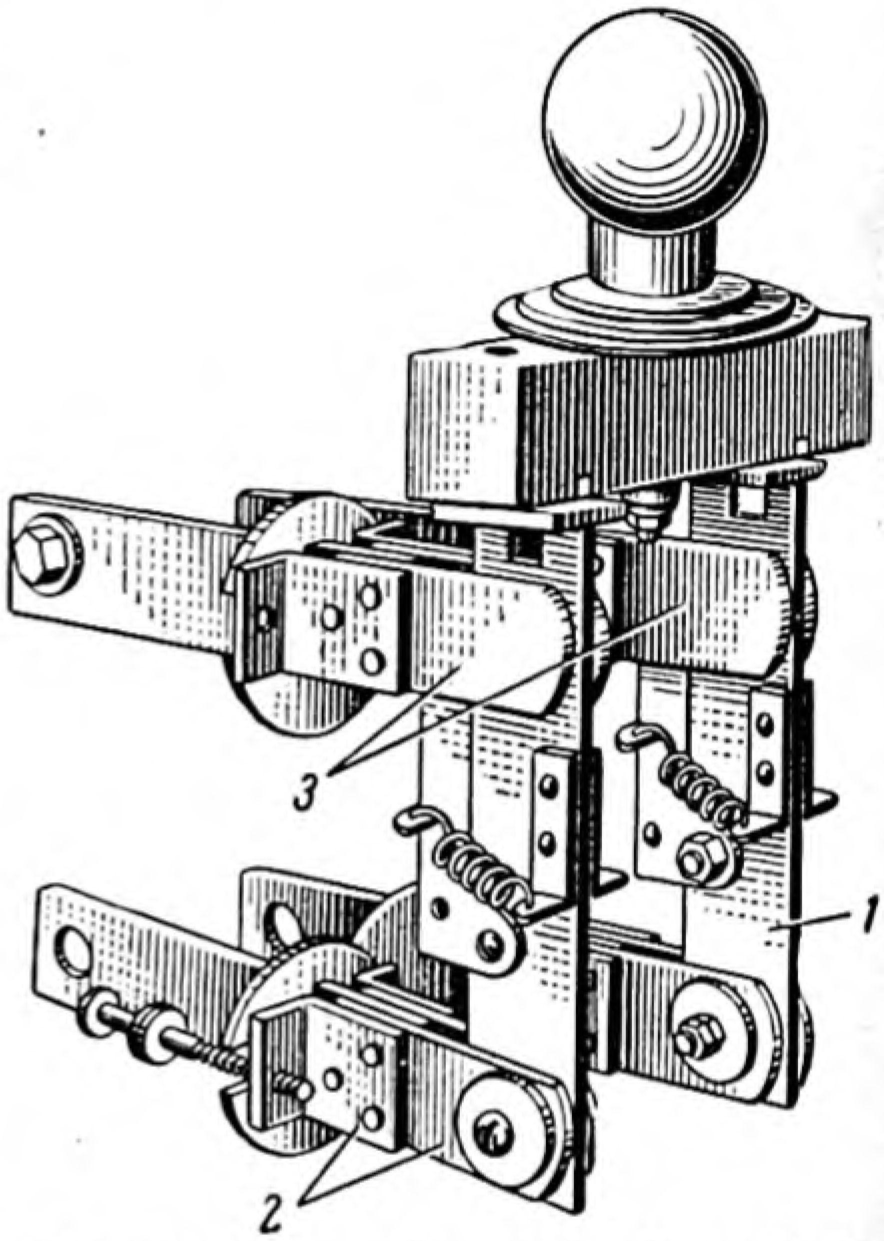


Fig. 20. Two-pole single-throw knife switch with central handle and without insulating board:

1—moving knife blades, 2—pivot contact clip, 3—contact clips.

The renewable fuse links for them are made for current ratings of 15, 60, 100, 200, 350, 600 and 1,000 amperes. The fuse links are stamped from sheet zinc and have two narrow necks for short cases (rated up to 220 v) and four narrow necks for long cases.

The broad- and narrow-necked portions of the fuse link serve to protect it and the entire fuse from overheating when the load

nonrenewable, are rated for 500 volts and have a high power breaking or interrupting capacity which is attained by using a filling (quartz-sand). The quartz-sand fosters intense deionising of the electric arc which appears during blow-out of the fuse link. The nonrenewable НПН (NPN) fuses are made for a current rating of 40 amp; the НПР (NPR) renewable fuses are available with current ratings

of 100, 150, 250, 400 and 600 amp.

The lighting switches, and plug and sockets discussed above are used where the value of the current is small (generally within a limit of 6 amp). For accomplishing changes in circuits designed to carry large currents, particularly in power installation circuits, use is made mostly of single-throw knife switches, double-throw change-over switches and special rotary (or packet) switches.

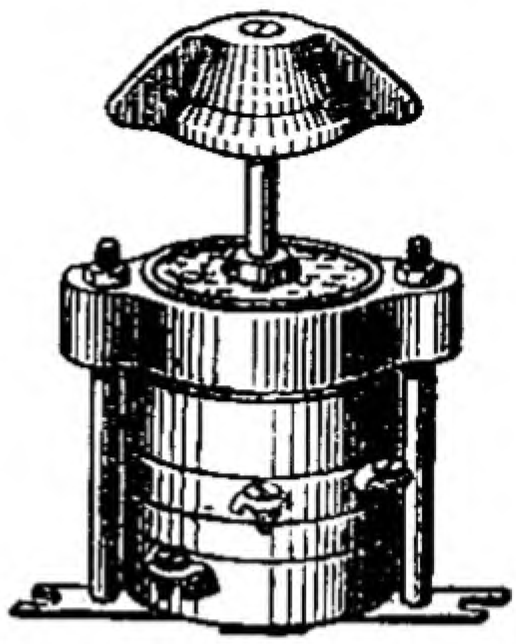


Fig. 22. Three-pole rotary or packet switch.

Fig. 20 shows a two-pole, single-throw knife switch with a central handle rated for 500 v, 100 a and designed for back connection of the wiring.

Double-throw change-over switches differ from single-throw knife switches in that they have a second set of contact clips (Fig. 21). Such switches are in a closed position when the middle pivot contact clips are connected by their knife blades either with the upper set of contact clips or with the lower set of contact clips.

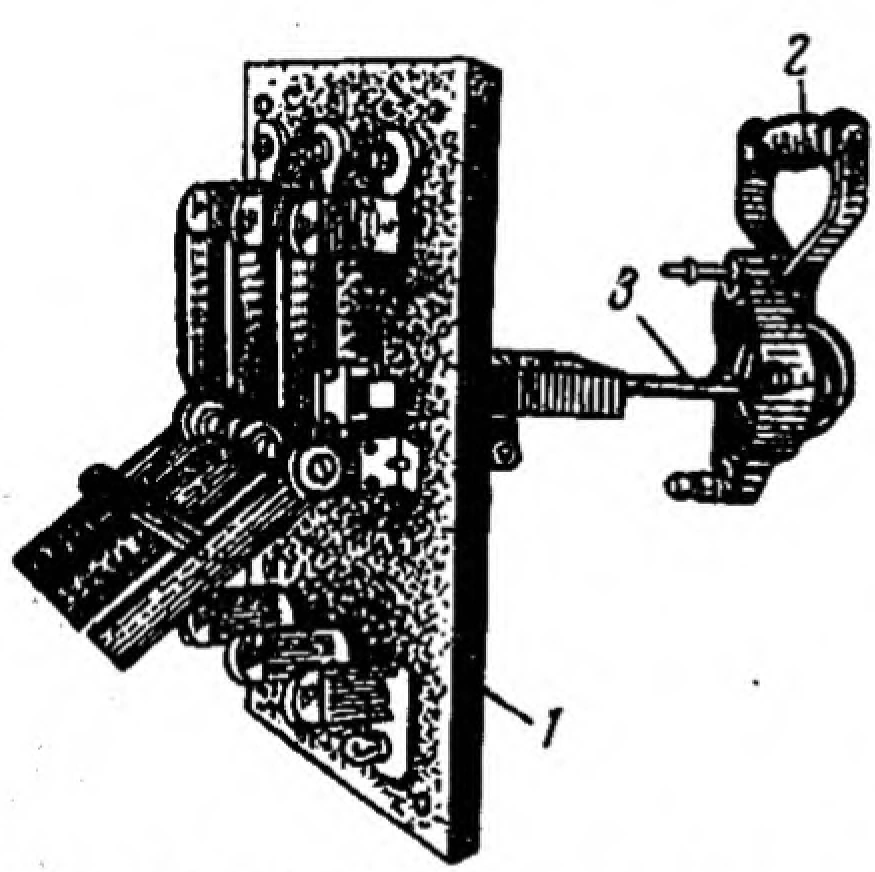


Fig. 21. Double-throw change-over switch with a lever operating mechanism:
1—insulating board, 2—lever operating mechanism (for mounting on switchboard face panel), 3—tie rod.

Single-throw knife switches and double-throw change-over switches may have single-pole, two-pole and three-pole contact systems. If they are intended for mounting on insulating switchboard panels, they are furnished without a base (see Fig. 20). If intended for mounting on noninsulating supports (metal panels, frameworks) or walls, they are furnished mounted on insulating boards (Fig. 21).

Rotary (or packet) switches (Fig. 22) and two-way switches of the same type are built up from single-pole section elements and are available in single-pole, two-pole and three-pole versions rated for 380 volts. Their current ratings range from 10 to 60 amp.

To disconnect electric circuits from supply when abnormal conditions arise during operation, single-pole and three-pole air circuit breakers which

trip automatically are installed. They vary broadly as to features of construction. By means of such air circuit breakers it is possible to disconnect a circuit at a definite value of load current.

Fig. 23 gives a general view and the constructional features of a type A air circuit breaker.

The type A air circuit breaker (Fig. 23) is designed for currents of 6 to 20 amp and for mounting on branch-circuit lighting panel boards (to be studied later) in place of plug fuse units. These circuit breakers can be closed and opened by hand by throw-over of the operating lever.

Automatic tripping takes place in the following way. The current taken from supply flows into the circuit breaker through a bimetal strip (element) serving to latch the spring-loaded tripping mechanism in the closed position. In the event of an overload or short circuit in the protected circuit, the overcurrent which appears causes the bimetal element to heat and temporarily deform. Due to this, the trip-free mechanism is unlatched, the contacts of the circuit breaker open and the circuit is disconnected from supply.

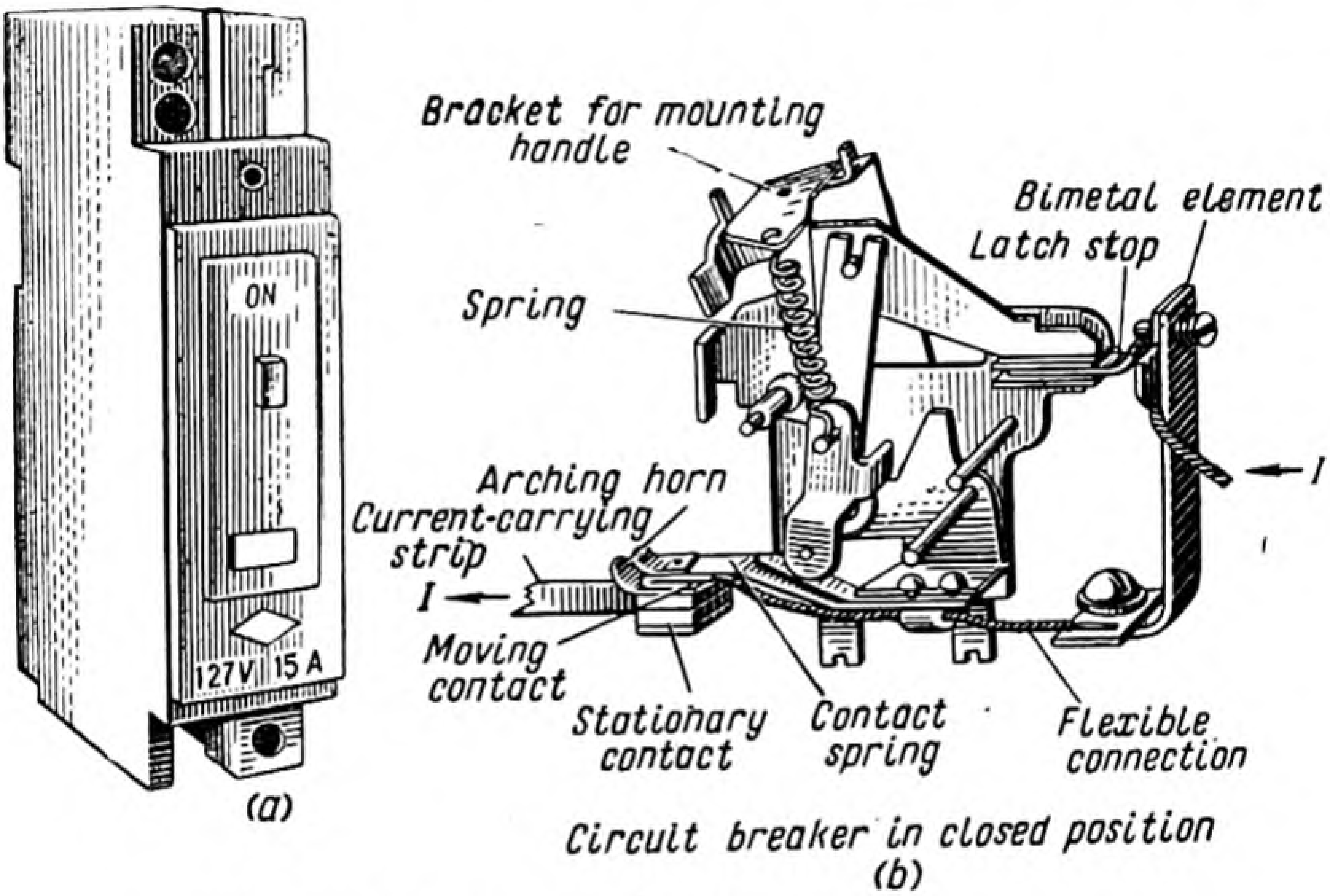


Fig. 23. Type A, single-pole air circuit breaker:
a—general view, *b*—features of construction.

After an automatic trip-out, the circuit breaker contacts can be reclosed and the circuit connected to supply again by throwover of the manual operating lever. When tripping occurs, the bimetal element in the circuit breaker quickly cools down, straightens out and again becomes able to latch the trip-free mechanism in its closed position.

Three-pole air circuit breakers provided with a trip-free

mechanism and electromagnetic overcurrent trips designed for large currents find application in three-phase circuits.

2. *Lighting Installations*

Lighting Fittings

The sources of light in electric lighting installations are incandescent lamps and fluorescent tubes.

(cold light) and do not have a distorted colour spectrum.

Fig. 24 gives a view of a fluorescent tube showing its features of design. Such a unit has the form of a glass tube coated on the inside with a thin layer of a phosphor compound. At both ends the tube is fitted with tungsten electrodes connected at their ends to twin-pin bases serving to hermetically seal the tube. By means of the brought-out ends of the contact pins provided to

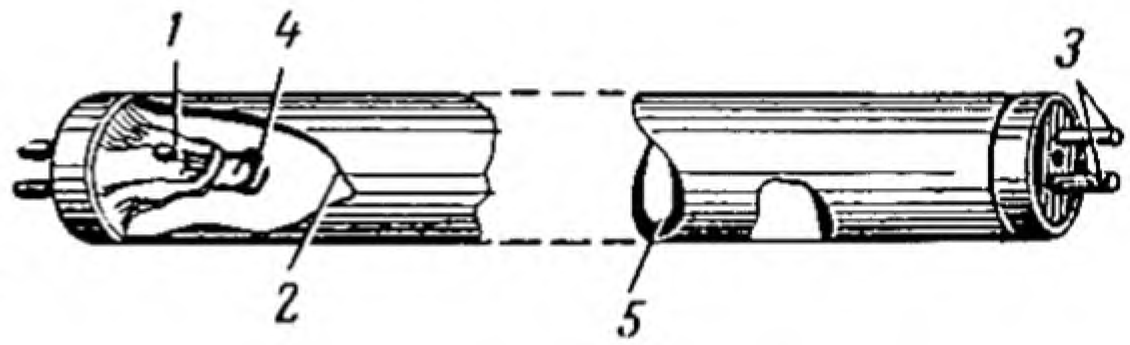


Fig. 24. Fluorescent tube:
1 — glass stem, *2* — glass tube, *3* — base contact pins, *4* — electrode, *5*—phosphor coating.

Incandescent lamps are manufactured for voltages ranging from 12 to 220 volts and for wattages from 10 to 1,000 watts. The screw base of lamps in ratings up to 300 watts has a screw-thread diameter of 27 mm, or the so-called normal thread. Lamps rated for 500 watts and greater have a base with a screw-thread diameter of 40 mm, i.e., with a "large thread". In limited types, lamps of low wattage are available with a "small-thread" base, of 14-mm diameter.

Fluorescent tubes, or, as they are sometimes called, daylight lamps, are considerably more economical in power consumption than incandescent lamps because, in contradistinction to incandescent lamps, they operate practically without heating

be slipped into special clip sockets, the tubes can be connected to the lighting circuit.

During manufacture the air is exhausted from the tube and a drop of mercury and a small amount of argon are introduced into it.

When the tube is connected to supply, an electric discharge is set up between its electrodes in the vapour of the mercury. This discharge becomes a source of invisible ultraviolet rays which impinge on the layer of phosphor where their energy is absorbed and cause the phosphor to radiate a visible light flux.

Incandescent lamps are connected to the lighting circuit by means of a lampholder or socket (Fig. 25). The main part of a lampholder is its porcelain insert block *1* carrying the atta-

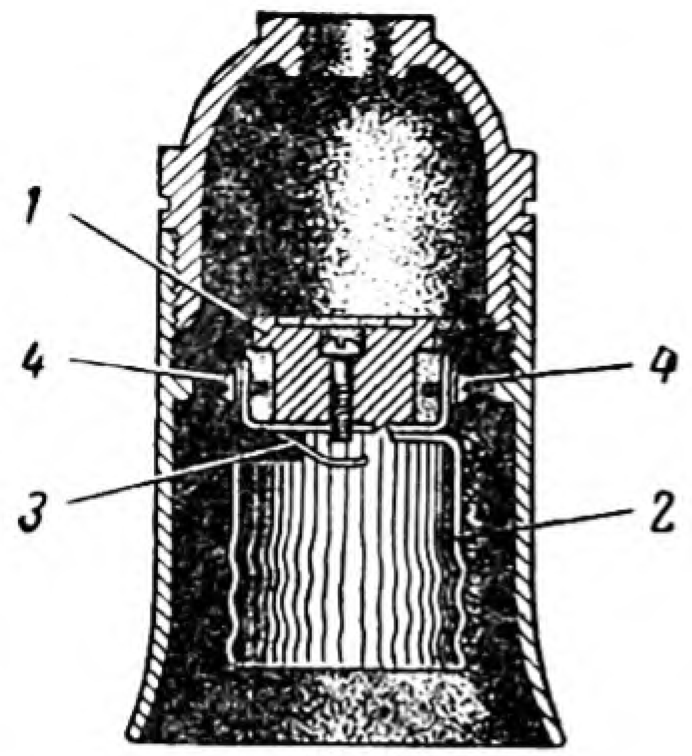


Fig. 25. Lampholder.

ched current-carrying components: screw shell *2*, internal contact *3* and two terminal screws *4* for connection of the circuit conductors (to the screw shell and the internal contact).

In accordance with the respective sizes of the lamp bases, lampholders may have a screw shell with a 27-mm normal diameter screw thread, a large screw thread of 40-mm diameter or a small screw thread of 14-mm diameter.

Distribution of the light flux from a lamp to suit different conditions and to avoid the blinding effect of its high brightness is accomplished by means of various lighting fittings.

For securing the lampholders in lighting fittings and for installing the fittings themselves, use is made of such fixing accessories as running-thread nipples (for ceiling-hung fittings), nuts, tubular hanger rods (for drop-hung fittings), hanger shackles and figure-eight hooks (Fig. 26).

For convenience, the lighting fitting and the lamp may be termed a *lighting unit.*

The most characteristic lighting fittings, their functions and the conditions for which they are best suited are given in Table 5.

Public buildings and houses are generally equipped with various forms of special lighting fittings (Fig. 27) and a wide variety of chandeliers.

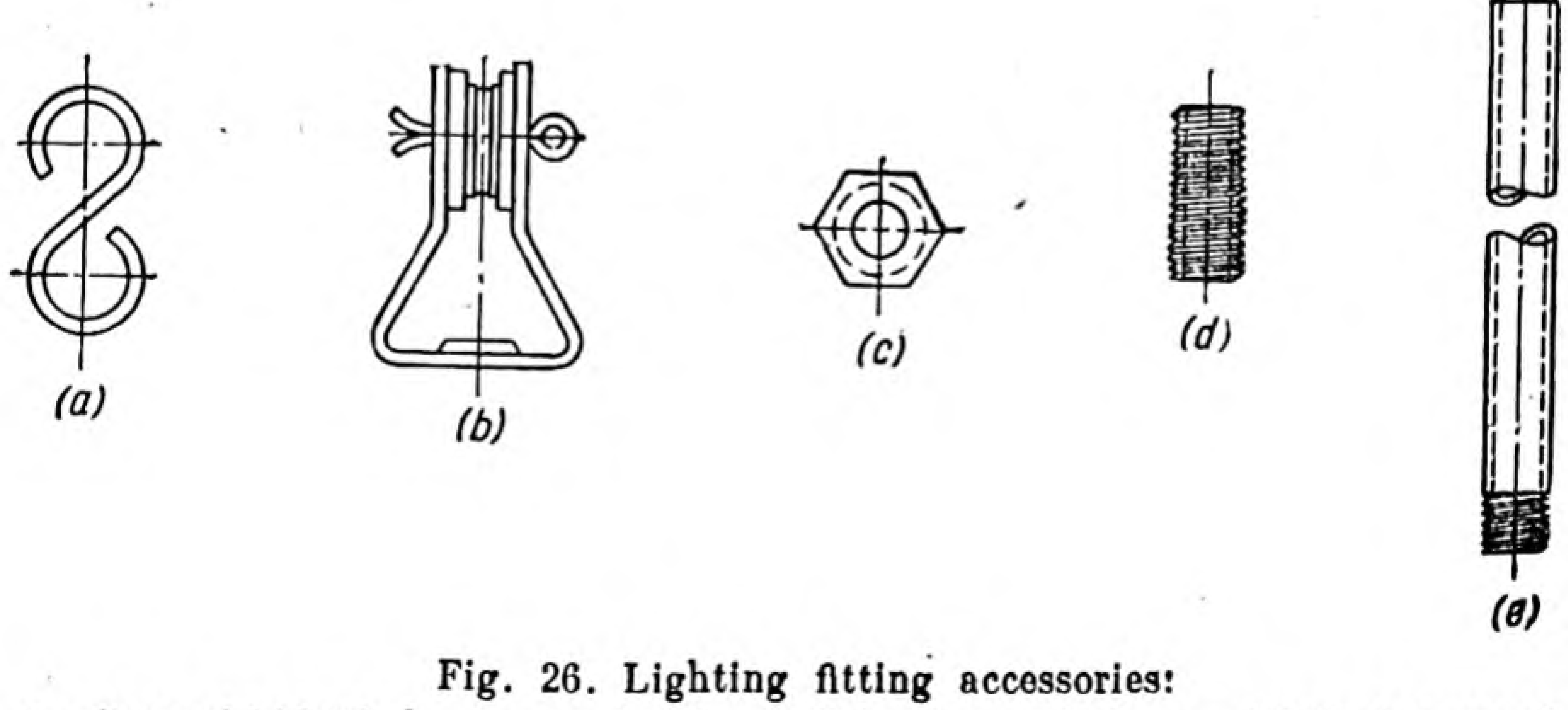


Fig. 26. Lighting fitting accessories:
a —figure-eight hook, *b* — hanger shackle, *c* —flat nut, *d* —nipple, *e* — tubular hanger rod.

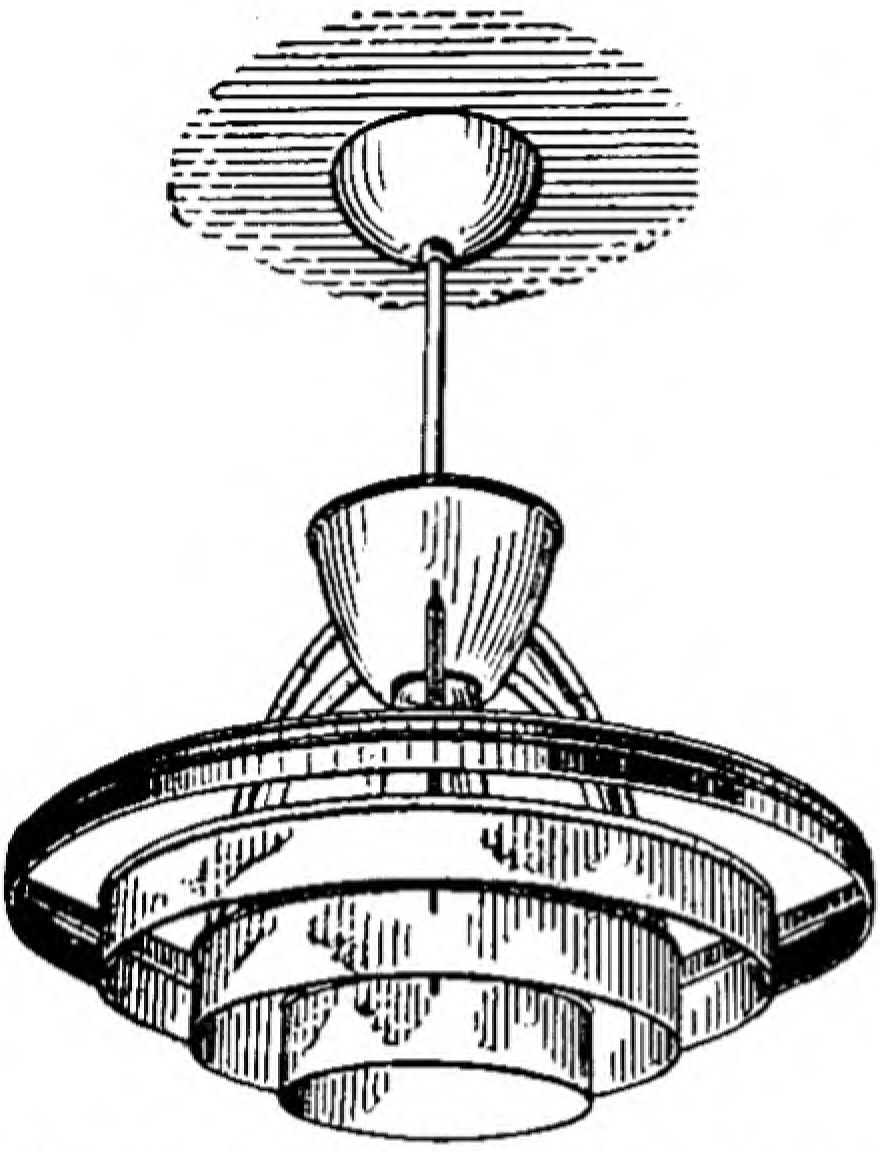


Fig. 27. Ring diffuser lighting fitting.

Systems of Lighting

Lighting installations are generally subdivided into three systems:

1. General lighting system — the installation designed for illuminating a given area or premises as a whole, for example, a shop, storeroom, garage, reading room, living room, etc.

The general lighting system serves to create the level of illumination prescribed for any given kind of room or work place by acting lighting Regulations. The intensity or level of illumination to be provided depends upon the purpose for which the given room is intended and upon the character of the work to be done in the room.

The voltage at which general lighting systems are supplied ranges up to 250 volts.

Within heightened shock hazardous and highly shock hazardous premises, when ordinary lighting fittings are installed at heights less than 2.5 metres from the floor, the general lighting system supply voltage must be limited to 36 volts.

2. Local lighting—the part of an installation designed only for illuminating individual work places. Local lighting can be stationary (permanent), for example, at a work bench, machine tool, classroom blackboard, etc., and also portable, as for example, in a garage where repairs and inspections of automobiles are carried out and when work has to be done inside a boiler or in rarely attended places. For portable local lighting, special portable or hand lamps are used.

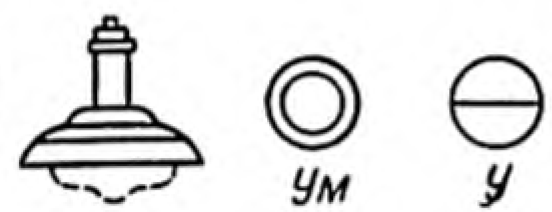
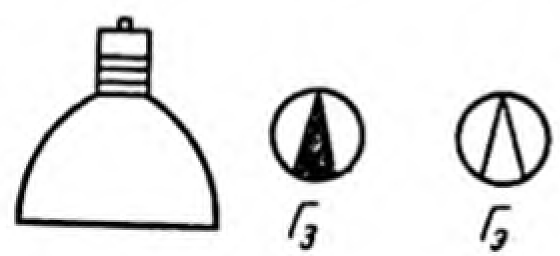
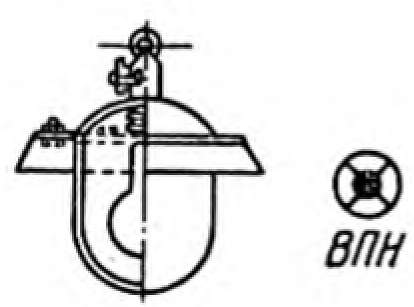
Another example of stationary local lighting is a lamp set placed on a writing desk.

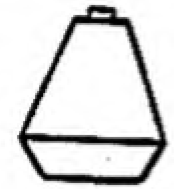
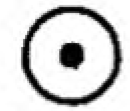
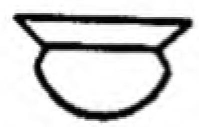
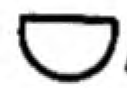
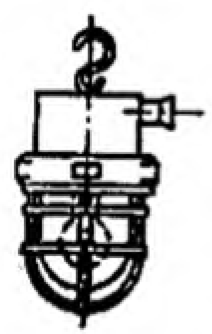
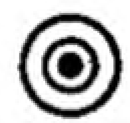
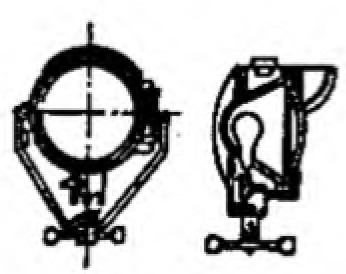
For stationary local lighting in heightened shock hazardous and highly shock hazardous premises, a supply voltage of up to 36 volts is permissible; for portable lighting in highly hazardous conditions (for example, when doing work in boilers, etc.), the supply voltage must not exceed 12 volts.

Supply both for general lighting fittings and for local lighting fittings fed at 36 volts and less is taken from the general lighting circuits. Local lighting fittings may also be supplied

Table 5

Characteristics and Field of Application of Most Widely Used Lighting Fittings

Name and symbol of lighting fitting	Form of design	Maximum lamp wattage	Field of application
"Alpha" reflector 	Open	60	For local lighting and suspension or bracket mounting in premises with normal atmosphere
"Universal", reflector with an opal glass diffuser $У_м (U_m)$ and without a glass diffuser $У (U)$ 	Enclosed	200 and 500	For general lighting systems in industrial premises with normal atmosphere at heights of suspension of 3 to 5 metres
Deep bay, intensive type reflector, with mirror reflecting surface $Г_з (G_z)$, and enamelled reflecting surface $Г_э (G_e)$ 	Open	300 and 500	For general lighting systems in industrial premises with normal atmosphere. For installation at heights of up to 10 metres
Water and dustproof lighting fitting 	Hermetic	200	For general lighting of premises with damp, wet, dusty or chemically active atmosphere. For installation at heights from 3 to 5 metres
Porcelain or moulded-plastic lighting fitting for damp atmospheres 	Semihermetic	60	For general lighting of premises with moist, damp or dusty atmosphere. For installation at heights of 2.5 to 3 metres

"Lutsetta"—opal one-piece glass lighting fitting		 Лц	Open	200 and 300	For general lighting in work rooms of public institutions. offices, class-rooms and other dry premises. For installation at heights of 3 to 5 metres
"Shar"—spherical opal glass lighting fitting		 Ш	Enclosed	200	For general lighting in auxiliary premises (corridors, staircases)
Close-ceiling lighting fitting (*a*—number of lamps, *b*—wattage of lamp)		 П $a \times b$	Enclosed	For one or two lamps, 50 to 100 w each	For general lighting in auxiliary premises by direct fixing to ceiling in low rooms
Mining type lighting fitting with clear glass well		 РН-60	Hermetic	100-150	For lighting of dusty and fire-hazardous premises, and also for premises with wet or chemically active atmosphere
Floodlighting units (*a*—wattage of lamp, *b*—angle of inclination, deg.)		 ПЗС	Dustproof	500 and 1,000	For lighting of approachways, construction sites, railway tracks, stadiums and large outdoor areas when mounted at heights of 15 to 25 metres

from the circuits of power installations through transformers.

3. Combined lighting system — an installation combining both general and local lighting. Such systems are primarily found in industrial establishments.

In certain cases general lighting systems consist of two forms: working and emergency.

The working lighting circuits operate under all ordinary working conditions, while the emergency lighting circuits are designed to provide illumination when a failure occurs in the working lighting circuit.

The working and emergency lighting circuits must receive their supply from different sources.

There also exist several other systems of lighting serving for special purposes such as for night-watchmen, advertising illumination, stage (theatre) illumination, etc.

Structure of Lighting Installations

The electric lighting installation of any particular building, shop or a whole enterprise is built up of definite consecutively arranged elements.

Fig. 28 gives a structural scheme for the electric lighting installation of a multi-storey two-section apartment house in which the first section has service entrance *6* and the second section service entrance *9*, the service connection being made by underground cables *7* and *8*.

To supply each house section, riser main *5* is run upward from the service entrance box and at each storey is tapped to storey distribution boards *4* from which feeder lines are taken off to supply the electric circuits of each flat on any given floor.

Where the feeder is brought

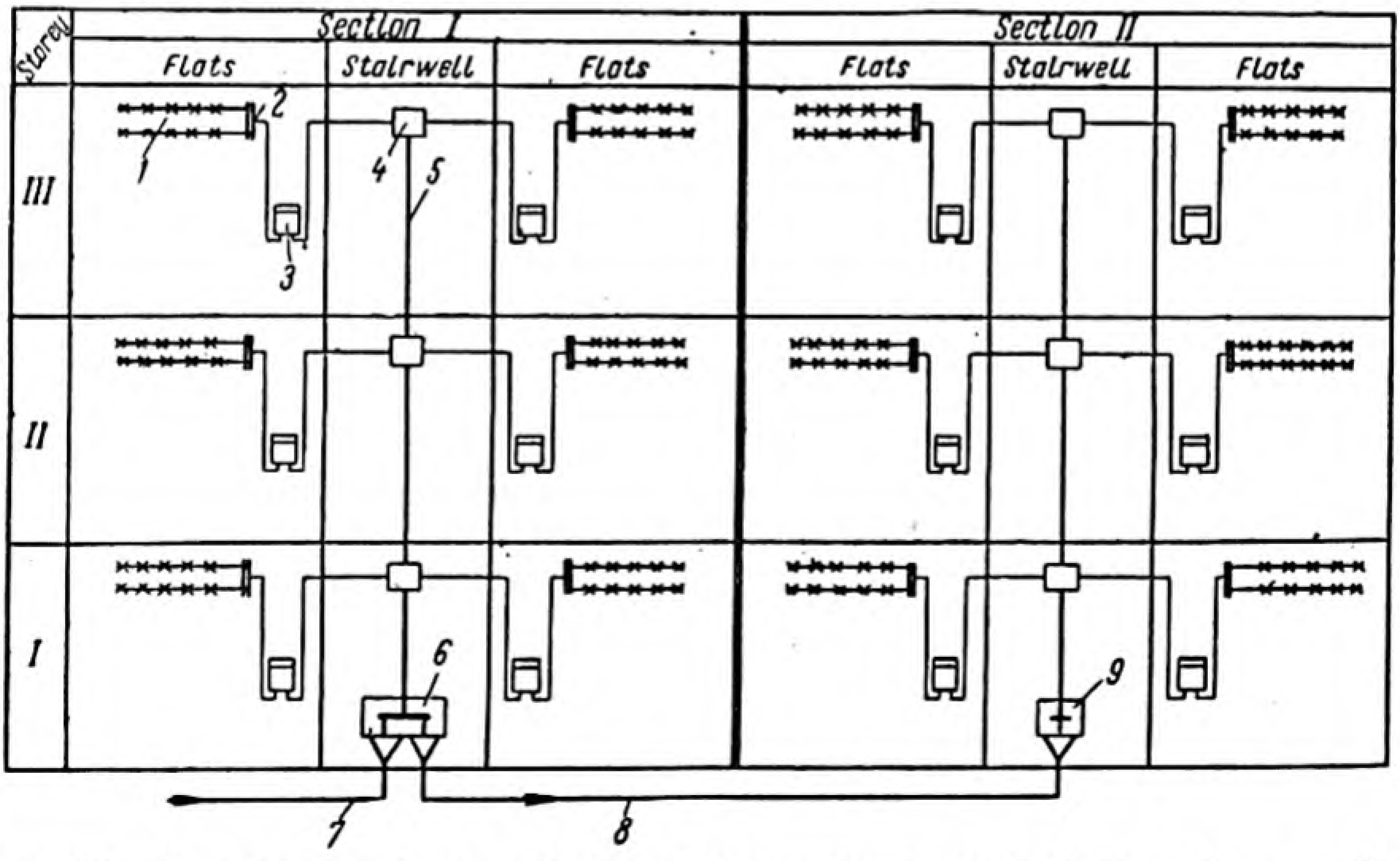


Fig. 28. Structural scheme of the lighting-circuit installation for a multi-storey two-section apartment house.

inside an apartment, a meter *3* is installed to register the electricity consumption of the flat. The branch fuse board *2* is installed directly after the meter. From it, branch circuits *1* are arranged to supply the lighting units and appliances used in the flat.

Fig. 29 shows the lighting circuit arrangement of a small industrial enterprise in which certain shops (shop *2* and shop *3*) have general and local lighting and, in addition to the working lighting circuits, an emergency lighting circuit.

The lighting installation of this enterprise has two service entrances: working lighting service *5* and emergency lighting service *6*, from which are run distribution circuits *3* and *4*. Supply to the general lighting systems is brought into the shops by branch circuits run from shop distribution boards *1*. For local lighting, supply is taken from low-voltage circuits (at, for example, 36 volts, obtained through step-down transformers *2* fed from the same shop distribution boards).

It is not infrequent to take supply for local lighting in industrial shops from the shop power installation circuits. In such cases the circuit which supplies power to the motors of a machine tool, a machine or a mechanism is tapped.

The consumption of electricity by the lighting system in an enterprise is generally registered by meters mounted either in the substation of the given enterprise or directly at the service entrance; meters may also be mounted in the different shops to register consumption by shops.

The supply circuits which feed power to lighting installations begin at the step-down power transformers in the substations. These circuits are, as a rule, four-wire three-phase, with the neutral of the system earthed, and are rated for 380/220 volts and, more rarely, for 220/127 volts. Still more rarely used is a three-wire three-phase system with a voltage of 220 or 127 volts.

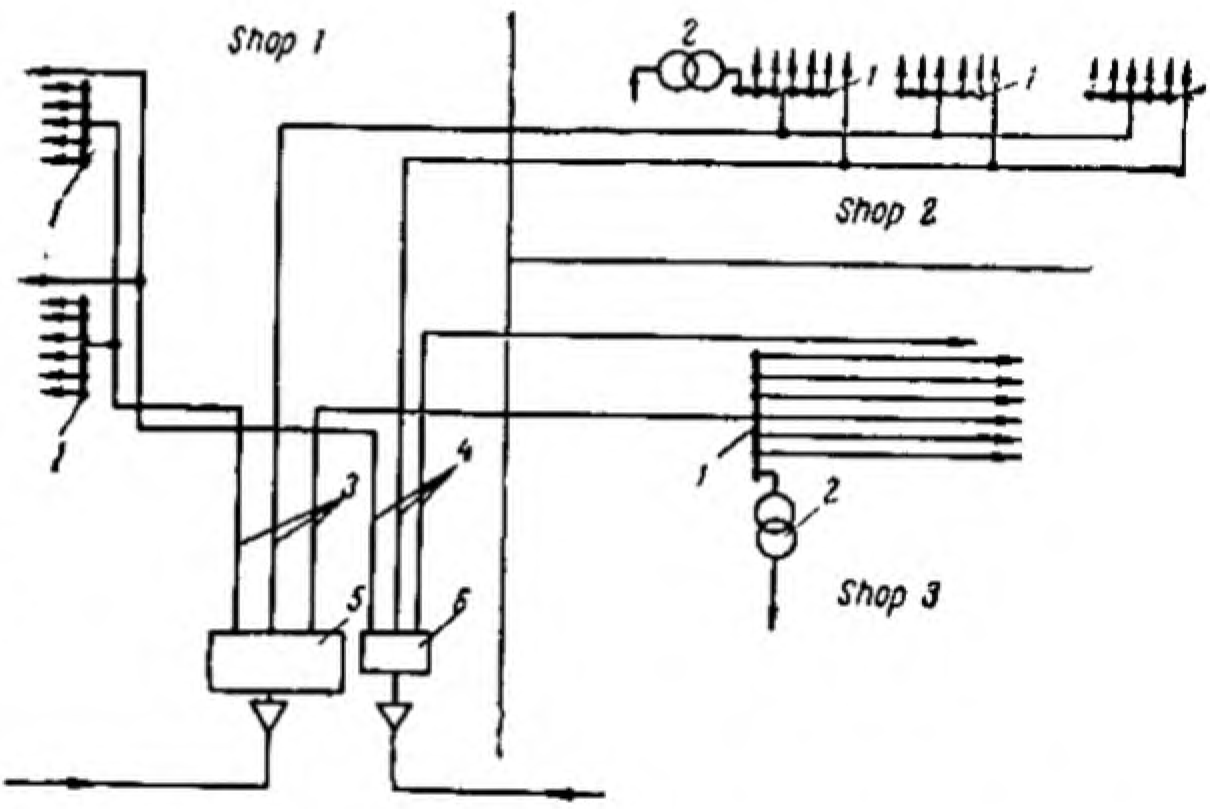


Fig. 29. Lighting circuit structure of a small industrial enterprise:
1—branch circuit distribution boards placed in shops, *2* — step-down transformers for local lighting supply, *3*—working lighting distribution circuits, *4*—emergency lighting distribution circuits, *5*—service entrance for working lighting supply, *6*—service entrance for emergency lighting supply.

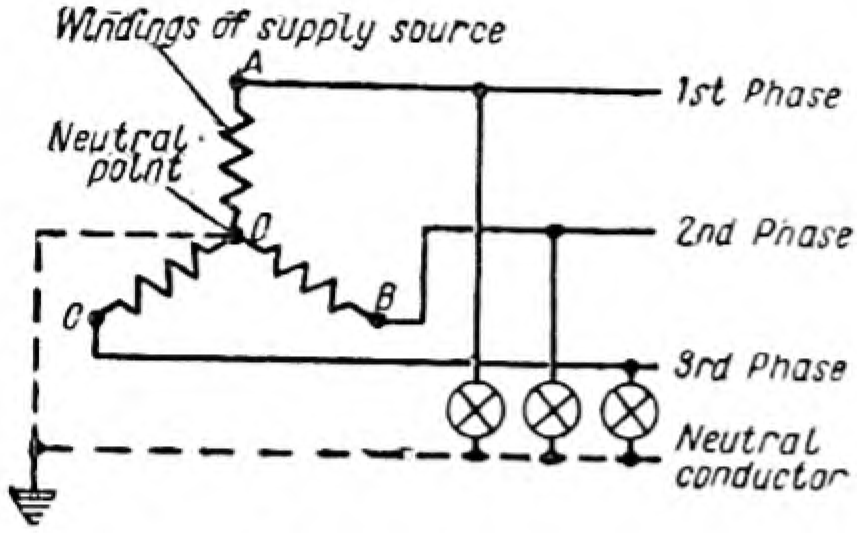


Fig. 30. Four-wire supply system.

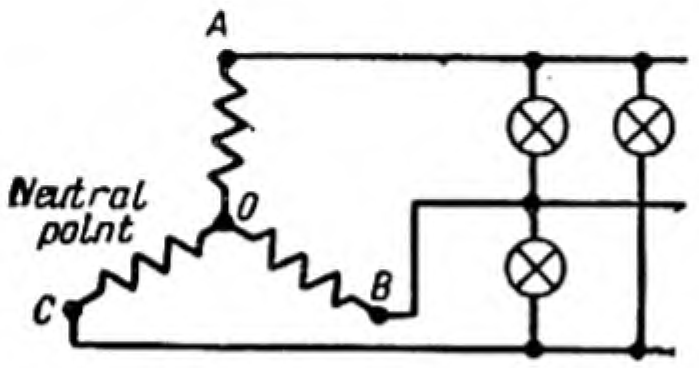


Fig. 31. Three-wire supply system.

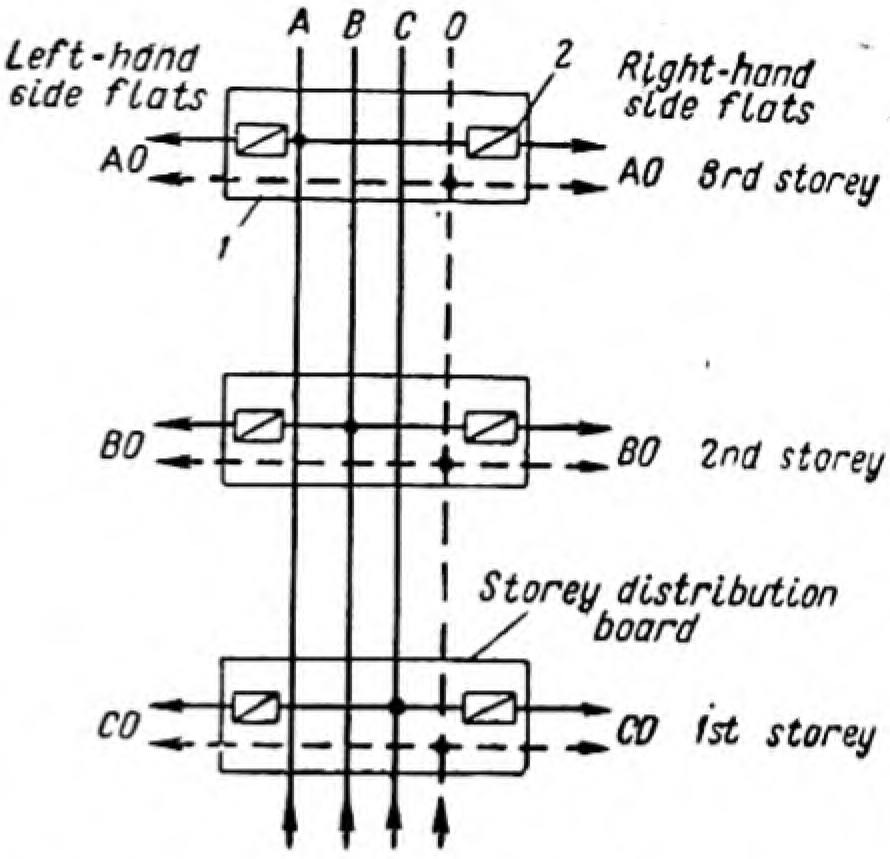


Fig. 32. Connections made from a four-wire riser main to storey distribution boards and the outgoing two-wire feeders run to each flat.

In the four-wire supply system (Fig. 30) the lighting circuit devices (lamps, small heating appliances, etc.) are connected between a line and the neutral conductor, i.e., to the 220-volt phase voltage (in a 380/220-volt system), or to the 127-volt phase voltage (in a 220/127-volt system).

In the three-wire supply system (Fig. 31) the lighting circuit devices are connected between two of the line wires *A*, *B* and *C*, i.e., across the line voltage.

The branch circuits (see *1*, in Fig. 28) connected to branch fuseboards *2* are installed as two-wire lines having a voltage of 220 or 127 volts.

The branch circuits of indoor lighting systems must be protected by fuses or circuit breakers rated for a working current not over 20 amp. As a rule, not more than 20 lamps should be connected to each branch circuit, this number including the plug sockets.

In multi-flat apartment houses having lightly loaded circuits the transfer from four-wire or three-wire supply to two-wire distribution is accomplished by means of the storey distribution boards provided at each floor in the stairwells (see Fig. 28).

To load uniformly each of the three phases (Fig. 32), the same total number of feeder circuits should be run to all the flats from each phase tapped at the storey distribution boards *1*, each such feeder to a flat being protected by fuses *2*.

In the lighting installations of various departments in industrial undertakings, administrative and business institutions, hospitals, educational institutions and other consumers

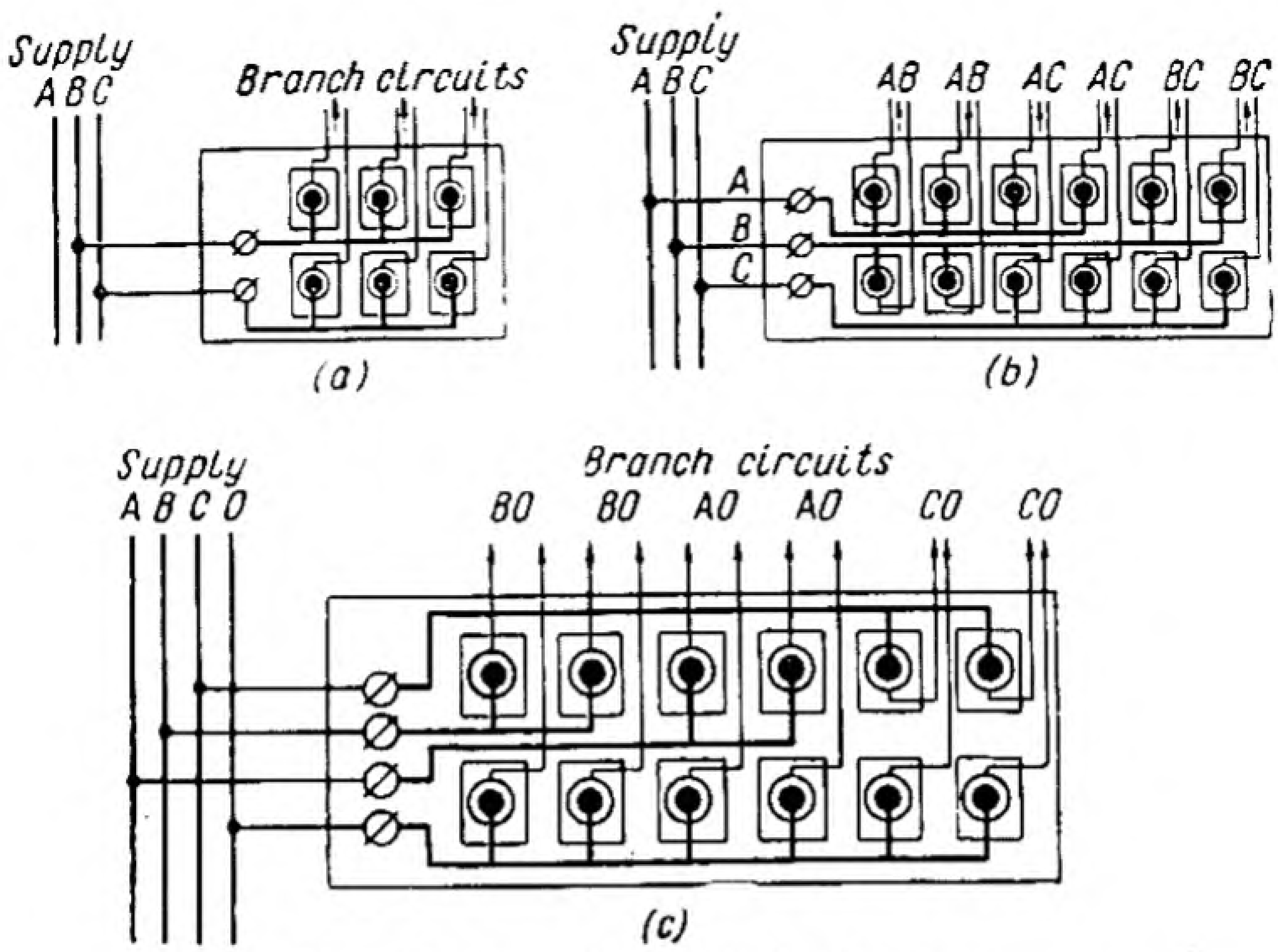


Fig. 33. Branch-circuit fuseboards:

a—connections of three-circuit fuseboard with two-wire supply from a three-phase, three-wire main, *b*—connections of a six-circuit, three-phase fuseboard with three-wire supply, *c*—connections of a six-circuit, three-phase fuseboard for supply from a four-wire main.

with large loads, the transfer from a four-wire or three-wire supply system to two-wire distribution is carried out directly at the branch-circuit boards connected for this purpose according to definite arrangement schemes.

The branch-circuit board connections depend upon the system of supply and the number of outgoing branch circuits. The latter must be uniformly laid out so as to carry nearly equal loads.

A fuseboard with single-phase (two-wire) supply is the simplest connection arrangement.* The connections for such a board designed for three branch (or group) lines are given in Fig. 33*a*. All the connections are usually made at the back of the board with small-size copper or aluminium bus-bars.

Fuseboard connection schemes for three-phase, three-wire supply must have each outgoing branch circuit connected through fuses to two different phases. Fig. 33*b* shows the connections for such a fuseboard (with six branch circuits) supplied at 127 or 220 volts.

With four-wire, three-phase system supply (at the voltage of 220/127 or 380/220 volts), each branch circuit is connected to the neutral-conductor bus and one of the line buses on the fuseboard (Fig. 33*c*), i.e.,

* Branch-circuit fuseboards, as well as floor distribution boards, belong in the group of simplest elements for distribution switchboards for voltages up to 500 volts; the latter will be discussed in more detail in Sec. 4 of the present chapter.

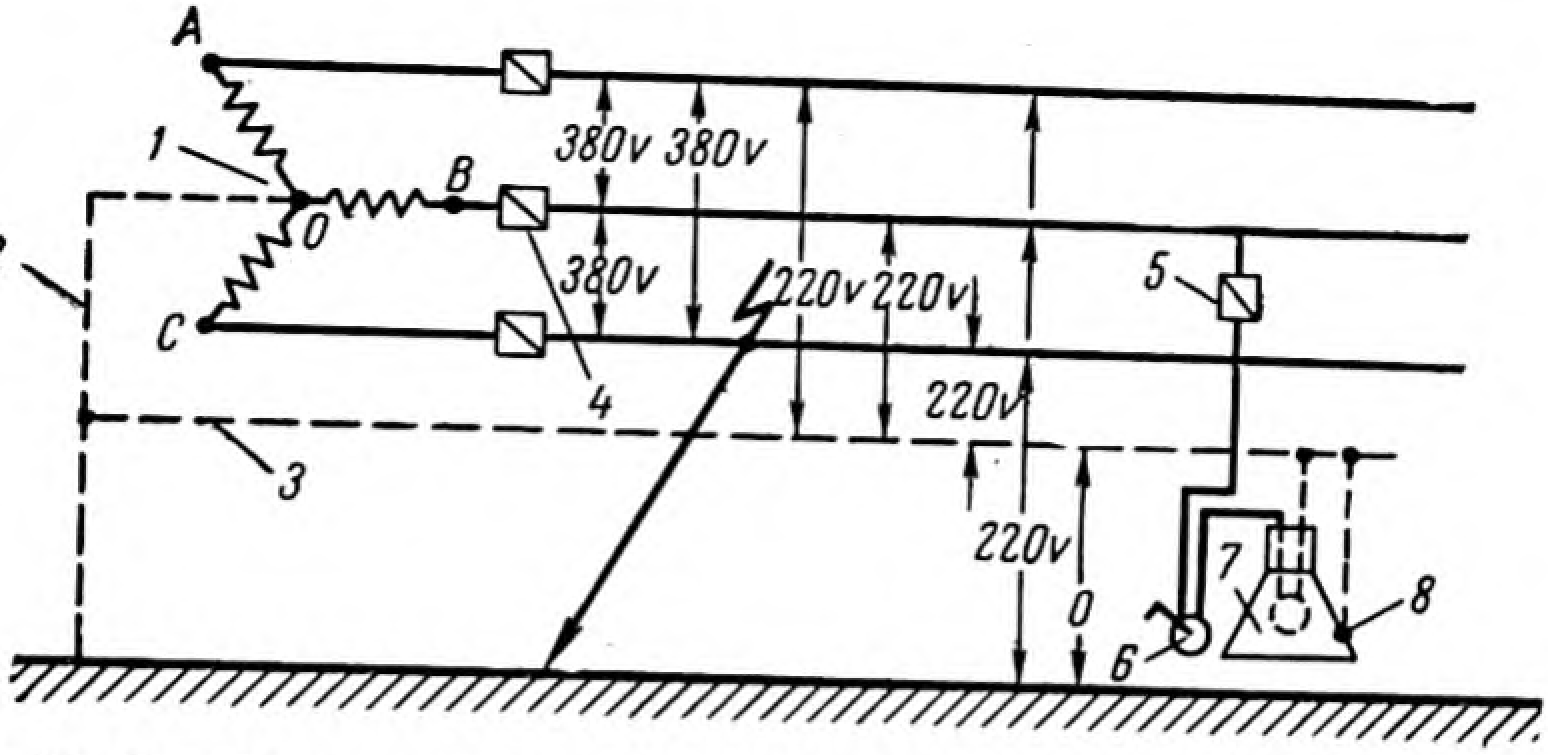


Fig. 34. Circuit arrangements of lighting installations supplied at 380/220 volts:

1—three-phase secondary winding of power transformer, 2—neutral earthing conductor used to earth neutral point of transformer, 3—neutral conductor of three-phase four-wire system, 4—fuse inserted in line wire of supply main, 5—fuse provided for lighting branch circuit on fuseboard, 6—single-pole lighting switch, 7—metallic part of lighting fitting, 8—earthing connection of lighting fitting body.

is connected across a phase voltage (127 volts in a 220/127-v system and 220 volts in a 380/220-v system). Fuseboards designed for 380/220-v supply have no fuses in the branch circuit conductors which make connection with the neutral of the supply circuit. This is due to the fact that circuits wired for such a voltage must satisfy definite requirements.

The Regulations permit lighting installations to be supplied only at a low voltage (i.e., not over 250 volts with respect to earth). To satisfy this requirement, the neutral point of power transformers used to supply lighting circuits through 380/220-v four-wire lines is earthed (Fig. 34) and connected to the neutral conductors in the supply lines. Consequently, any one of the line conductors, with respect to earth, will always be at a voltage of 220 volts. If in such a system one of the line conductors is shorted to earth, a short circuit occurs between the given line or phase and earth, the fuse in the line blows out, and this particular line (phase *C*) is thus disconnected from supply. No fuse should be interposed in the neutral conductor of the supply line because the blow-out of such a fuse will break the system of connection with the neutral. This system is explained below.

Taking into account the high danger to life of a voltage of 220 v with respect to earth, the Regulations demand, for four-wire 380/220-v installations with an earthed neutral, that all metal parts which, under normal operating conditions, are not under potential, but may accidentally acquire potential, shall be connected to the neutral conductor. Thus, if the insulation on a conductor in one of the phases is damaged, and the conductor comes in contact with one of the metal parts earthed to the neutral conductor (for instance, the metal body of a lighting

fitting), a short circuit occurs and the fuse in the line conductor blows out (on 380/220-v fuseboards no fuse can be interposed in the conductor connected to the neutral). As a result, the line conductor is disconnected from the voltage.

Lighting Control Circuits

Various lighting control circuits have been developed for maximum convenience and economical use of electric lighting.

Fig. 35*a* shows a full-circuit diagram for switching two incandescent lamps with a single-pole lighting switch. The number of lamps in this circuit may be one, two or more.

On the wiring plan of a room such a circuit is represented by a single-line diagram (Fig. 35*b*).

Figs 36*a* and *b*, give a full- and a single-line diagram for a circuit controlling several lamps with two lighting switches, the circuit having one plug socket at its end.

In all cases the plug socket must be independent of the operation of the general lighting units, but it must be connected to the nearest point in the common supply circuit.

Figs 37*a* and *b*, show a "developed" diagram and a single-line diagram of a circuit for control of three lamps in one room by a chandelier multi-way switch. As may be seen from the developed diagram, the first turn of the switch lights one lamp; the second turn lights two lamps, but the first lamp goes out.

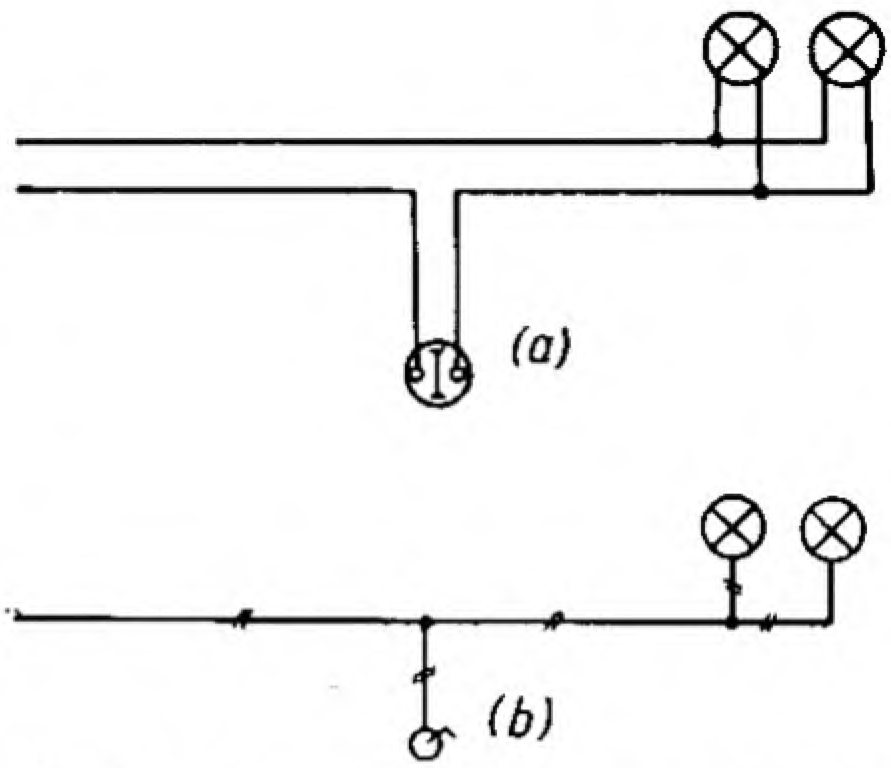


Fig. 35. Circuit for lamp control with a single-pole lighting switch:
a—full-circuit representation, *b*—single-line representation.

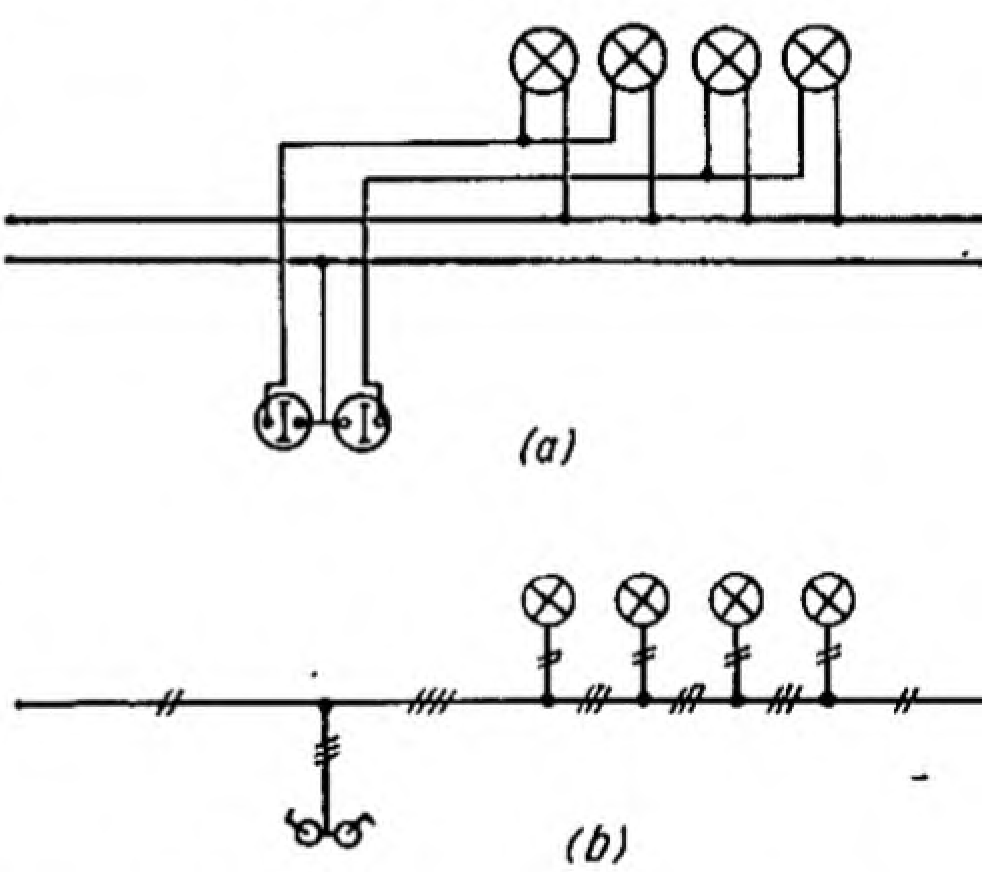


Fig. 36. Circuit for controlling several lamps with two (or more) lighting switches:
a—full-circuit representation, *b*—single-line representation.

The third turn will light up all the three lamps, and, when the fourth turn is made, all the lamps go out. The above circuit diagrams also show that a plug socket is connected in the circuit near the multi-way switch.

A circuit by which independent control of lamps from two different places is carried out

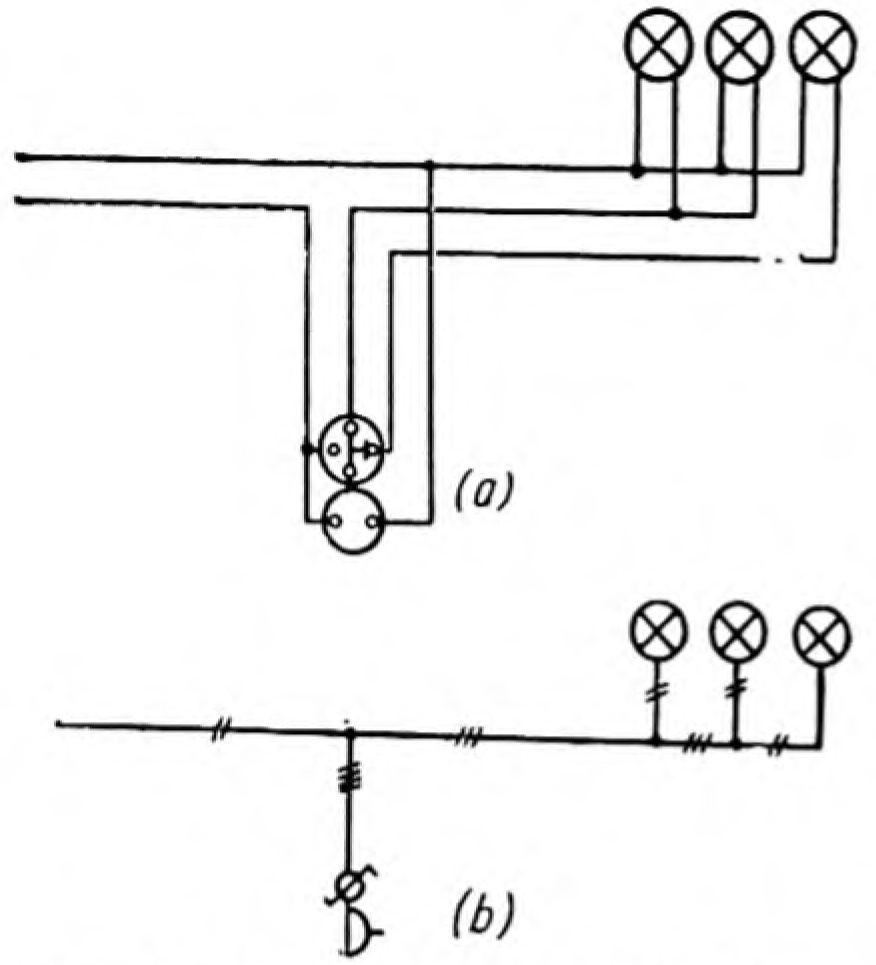


Fig. 37. Circuit for controlling lamps with a chandelier multi-way switch:
a—full-circuit representation, b—single-line representation.

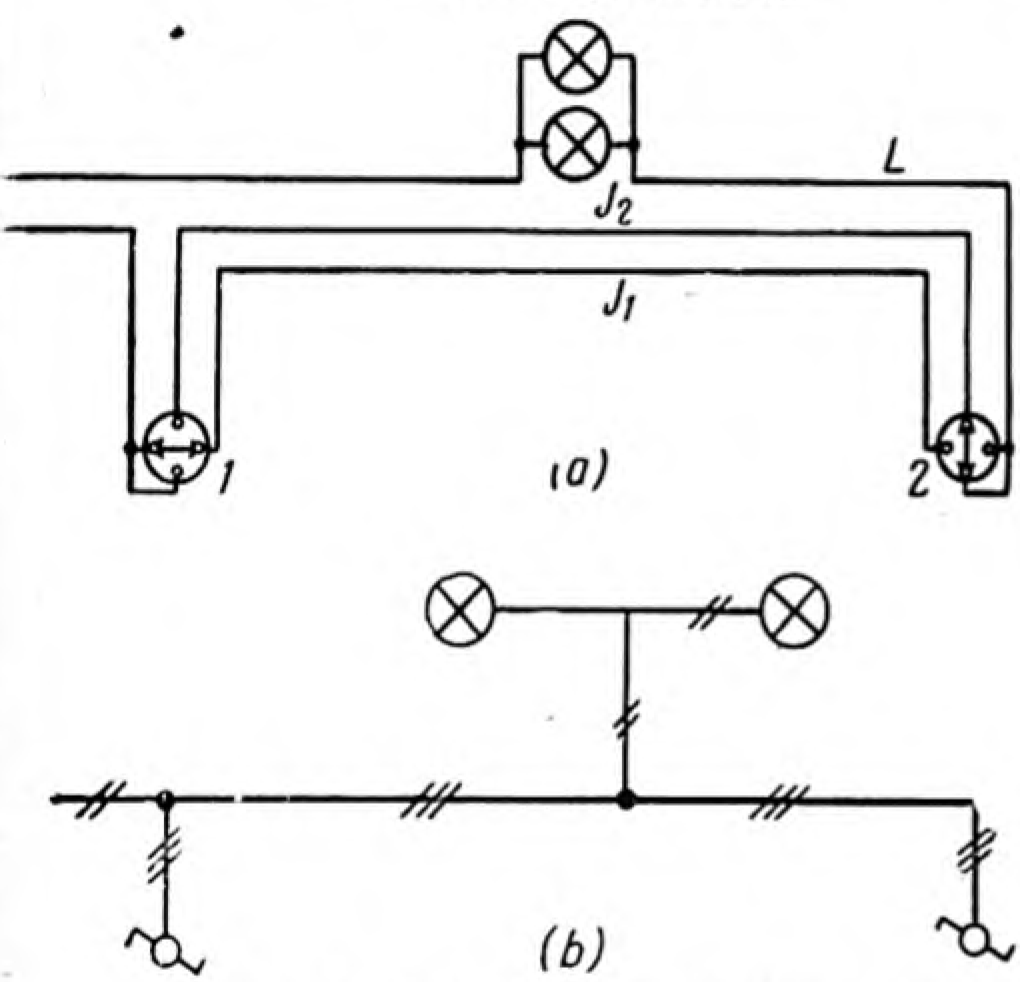


Fig. 38. Circuit for controlling a group of lamps from two different places:
a—full-circuit representation, b—single-line representation.

with the aid of corridor switches is shown in Fig. 38. It can be seen from the full-circuit diagram that corridor switch *1* transfers the supply from jumper J_1 to jumper J_2, and that corridor switch *2* performs the same operation with lamp conductor *L*. This makes the operation of the switches independent of each other, as each of them, in breaking the circuit, simultaneously prepares it for closing by the other switch.

Fig. 39 shows the same cir-

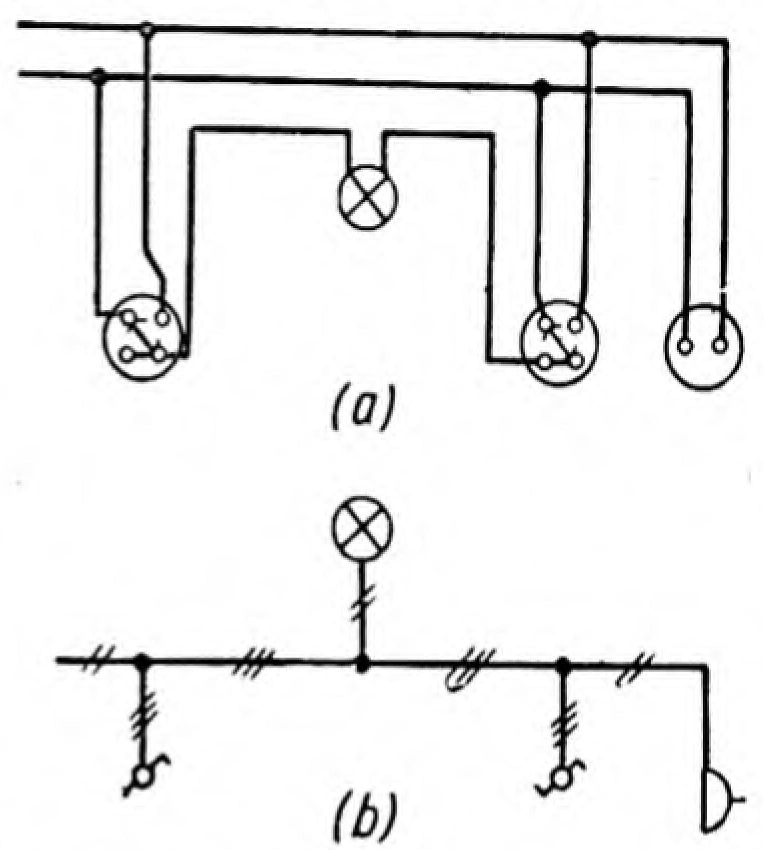


Fig. 39. Circuit for controlling a group of lamps from two different places and also having a plug socket installed at its end:
a—full-circuit representation, b—single-line representation.

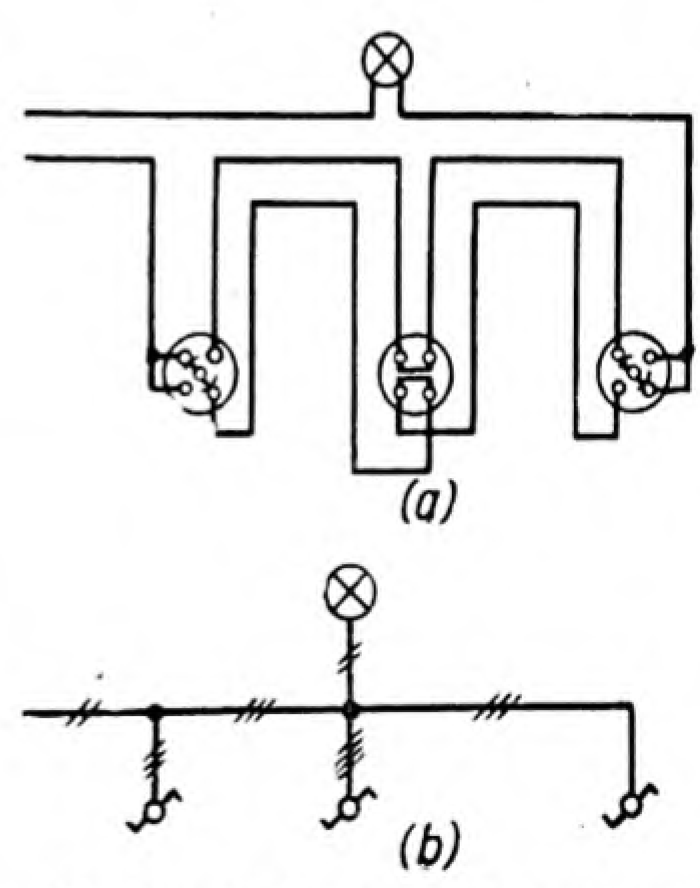


Fig. 40. Circuit for controlling a group of lamps from several places:
a—full-circuit representation, b—single-line representation.

cuit with a plug socket provided at the end of the circuit, while Fig. 40 shows a circuit used to control lamps from several places.

The above circuits take in all the main ways of controlling lighting installations with incandescent lamps (it is only possible to change the number of lamps and switches, change their positions relative to one another, include one or another number of plug sockets and arrange them at different places, etc.).

A fluorescent tube is connected in a special circuit (Fig.41) containing, in addition to the tube and a switch, a choke (coil with a steel core), and a starter device with a capacitor.

To ignite the lamp, it is necessary to pass current through the electrode circuit to first heat the electrodes. This operation is performed by the starter of the fluorescent tube.

The starter (Fig. 42) is a miniature-size neon lamp provided with two electrodes, one of which has the form of a bent bimetal strip. When the lighting switch completes the circuit to supply, a glow discharge develops in the neon gas between the starter electrodes. It heats the bimetal electrode, causes the latter to bend, and thus makes it come in contact with the other electrode. At this moment full current flows through the electrodes of the fluorescent tube, causing them to heat.

After the starter electrodes make contact, the glow discharge in the starter ceases, the bimetal electrode cools down and, in returning to its original position, breaks the circuit.

At the instant when the circuit is broken, because of the inductance of the choke, an impulse of high voltage is induced in the circuit. This voltage, which is applied across the hot fluorescent-tube electrodes, subsequently initiates the mercury vapour discharge in the tube which causes the tube to give off fluorescent light.

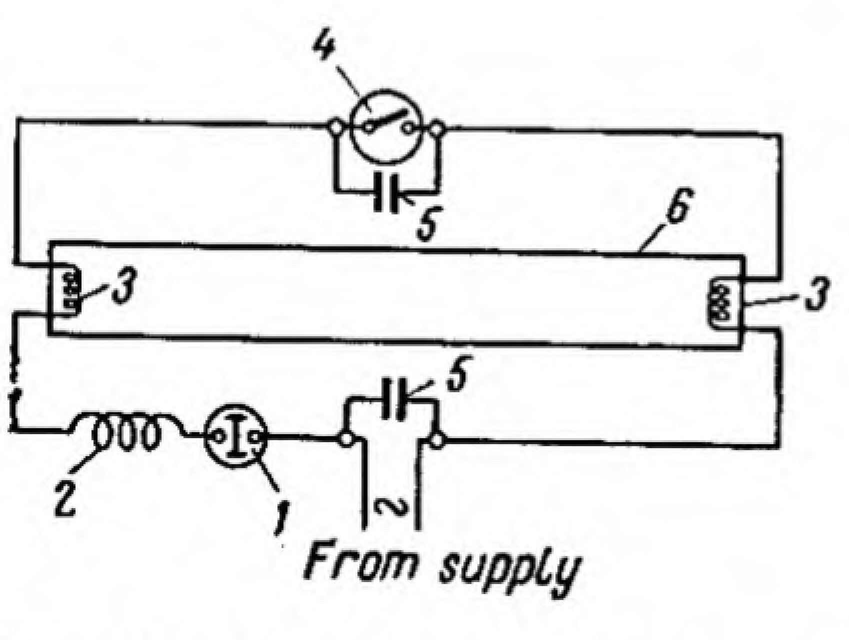


Fig. 41. Fluorescent tube control circuit:

1—switch, 2—choke, 3—electrodes, 4—starter, 5—capacitor, 6—tube proper

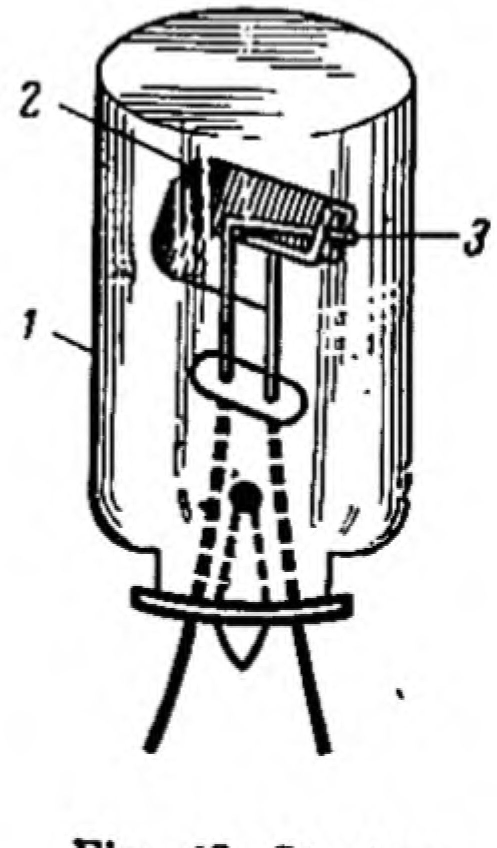


Fig. 42. Starter:

1—glass bulb, 2—bimetal moving electrode, 3—stationary electrode

3. General Features of Power Installations

Power installations are those in which the electric power receiving apparatus serves to convert electric energy into mechanical, heat and chemical energy.

Mechanical energy or power is of primary importance in any manufacturing establishment because it is needed to operate mechanisms, and run machines, machine tools and various devices.

The principal means serving for converting electric power into mechanical power are the various kinds of electric motors.

Alternating current (a-c) asynchronous or induction electric motors are the most widely used type of motor; they are simple in construction and easy to control. Only in special cases are direct current (d-c) motors used, such motors having the main advantage of permitting the speed to be smoothly adjusted over a wide range.

The power installations in industrial establishments consist of three-phase supply and distribution circuits taking the form of systems of wiring, distribution switchgear of a variety of types and purposes, and electric power receiving apparatus and their devices for starting and control.*

The electric circuits in the power installations of industrial establishments are installed according to radial and main-bus or trunk main connection schemes.

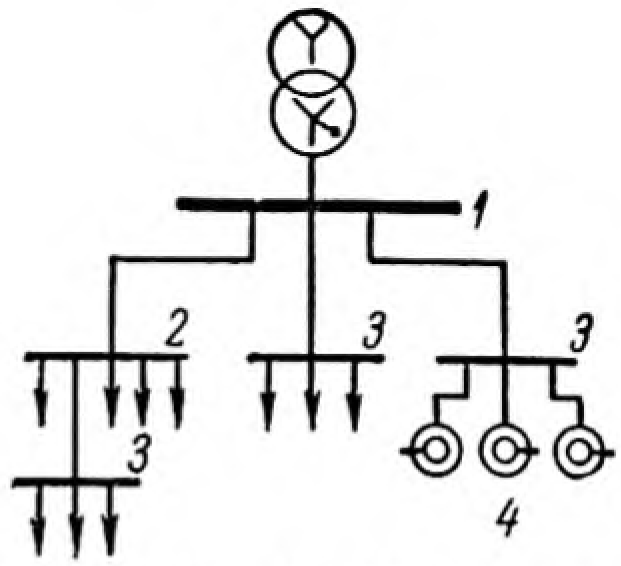


Fig. 43. Radial main connection scheme of supply.

A radial main connection scheme (Fig. 43) is used in cases where groups of electric motors are concentrated in separate places or areas. According to such a scheme, the feeders are run from a shop transformer substation switchboard *1* to power distribution cabinets *3* placed directly in the shop. The cabinets supply groups of electric motors *4* concentrated in specific areas.

Small distribution cabinets *3* in a shop may be fed from a main shop distribution-centre cabinet or switchboard *2*, the latter being connected by its feeder to the substation switchboard. It is also possible to use radial main connection schemes with other ways of arrangement.

Main-bus or trunk connection schemes may be of two forms: line main (Fig. 44*a*) and ring (or loop) main (Fig. 44*b*).

The ring-main trunk connection scheme differs from the line-main scheme in that it provides two-side supply, a feature which makes for considerable

* Power electrical equipment, the apparatus used to control it and their corresponding circuit connections are considered in Part V, "Power Electrical Equipment".

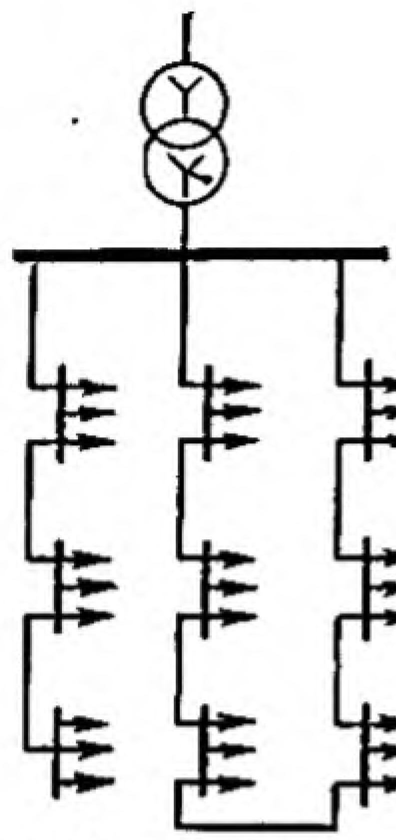


Fig. 44. Trunk connection scheme of supply:
a — line main scheme,
b—ring main scheme.

convenience when an emergency arises or repairs must be made.

Today metal-working establishments widely employ trunk main connection schemes in the form of busways (Fig. 45) installed in line with the rows of shop equipment (machine tools, mechanisms, etc.) for supply of their electric power units.

As can be seen in Fig. 45, by such a circuit arrangement the electric power units,

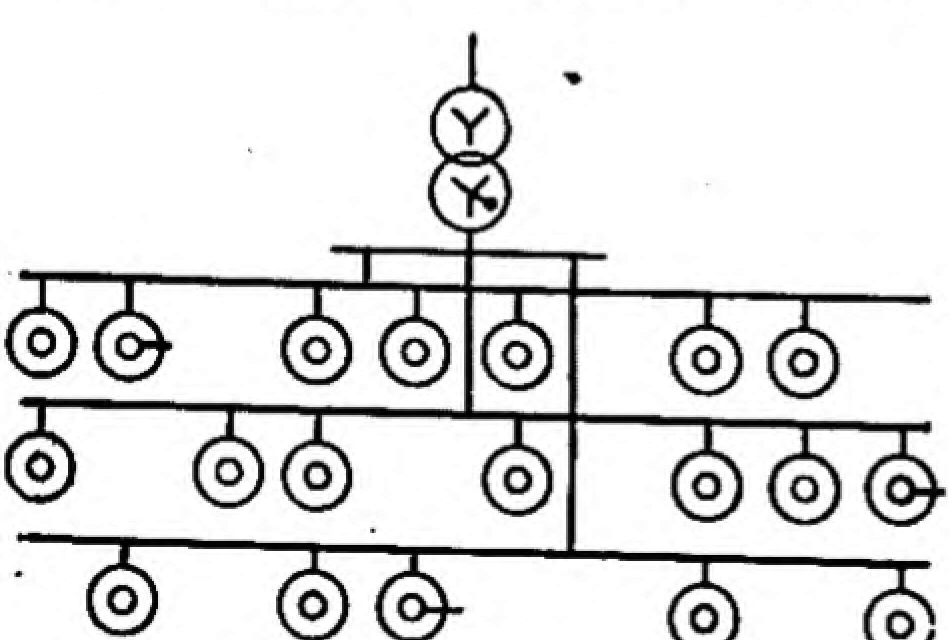


Fig. 45. Trunk connection scheme with supply take-off from busways.

wherever located in the shop, can always be connected to one of the rows of busway lines run through the shop. This method of connecting the electrical units is of great convenience where production shop equipment is frequently rearranged.

4. Design Features of Lighting and Power Distribution Equipment

For distributing purposes in lighting installations use is made of service boxes, service distribution cabinets, storey distribution boards and branch-circuit boards.

Fig. 46 shows a service box and its connection diagram. Such boxes are used in city cable distribution circuits for in-out

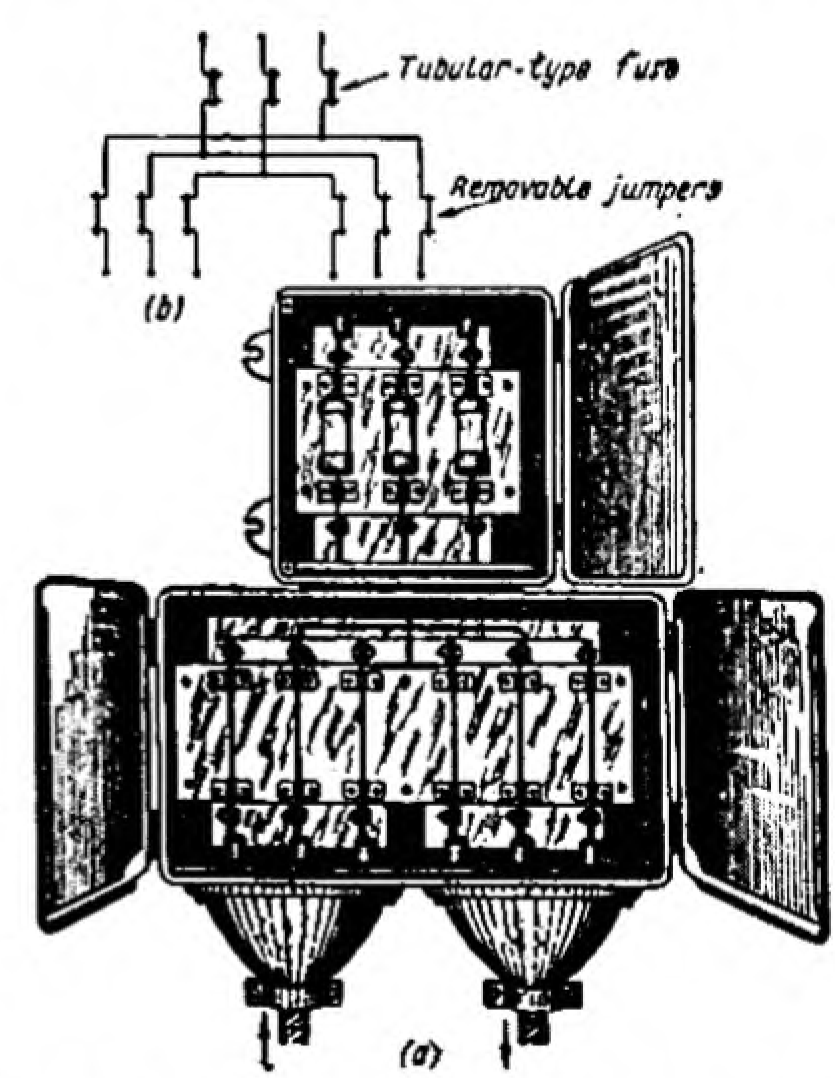


Fig. 46. Service box for in-out service cable distribution circuits:
a—general view, b—connection diagram.

connection of houses and public buildings.

An in-out cable service box, as can be seen from Fig. 46, makes it possible to do without an underground cable top-off which is difficult to install and is not always reliable in service. Any cable can always be cut out in such a service box by pulling out the corresponding removable jumpers.

A termination service box is one in which the last service cable of an in-out distribution circuit is terminated.

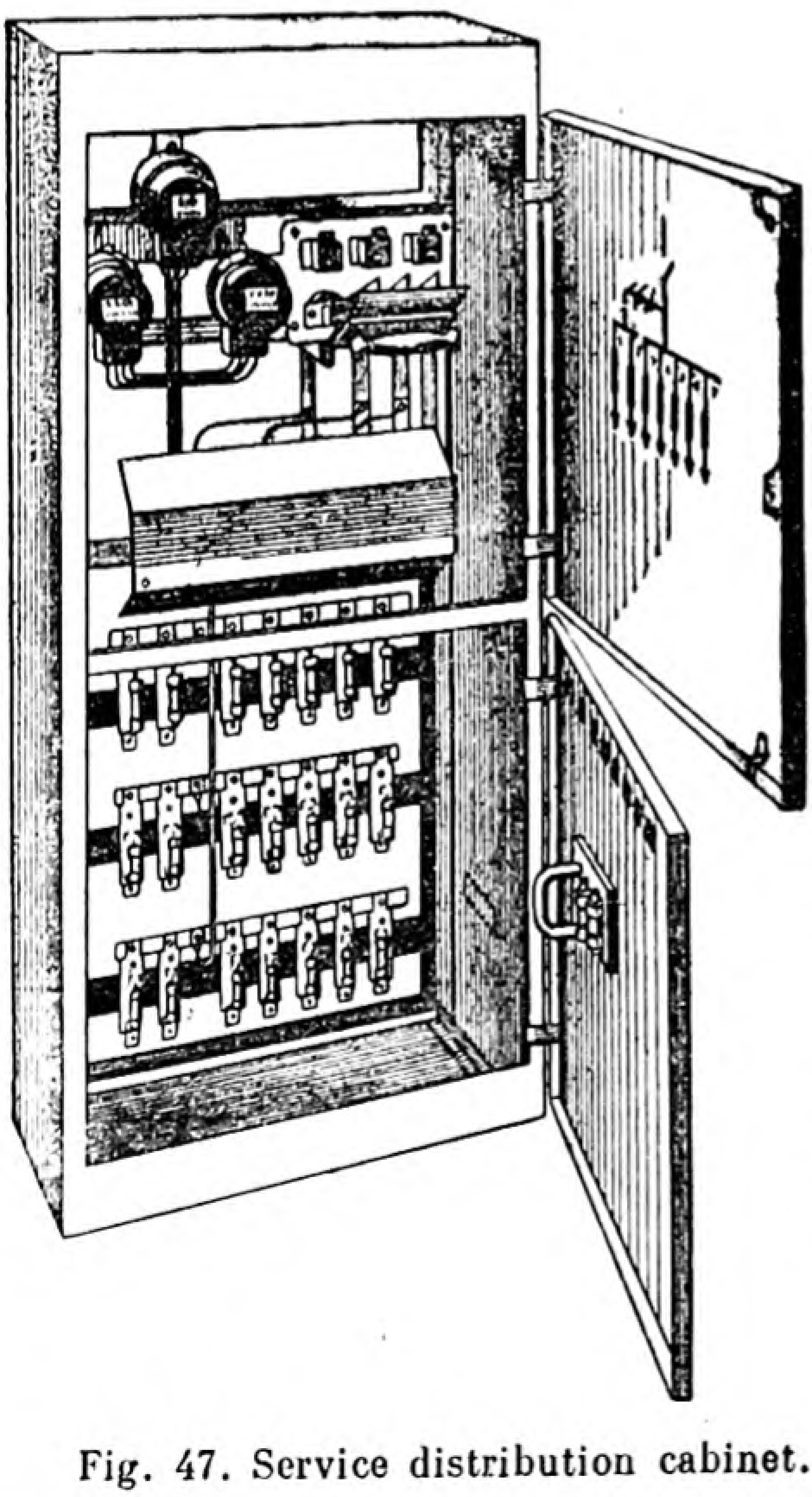


Fig. 47. Service distribution cabinet.

Fig. 47 shows the general features and the single-line diagram (on back of top door) of a service distribution cabinet installed at the service entrance of a consumer with a considerable load (commercial undertaking, educational institution, hospital, etc.). Mounted within such a cabinet are meters serving to register the power consumption in the outgoing distribution feeders.

A general view of a storey distribution board for take-off of four two-wire circuits is shown in Fig. 48. Such types of distribution boards are installed at each floor landing in the stairwells of large apartment houses where the riser mains are tapped by the feeders run into each flat.

The combined meter and fuse service board shown in Fig. 49 is in use today in apartment-house flats. It is of moulded plastic design and is provided with two sets of screw-plug fuses for two branch circuits and a space for mounting the meter directly on the board.

One of the forms of branch-circuit fuseboards (shop lighting distribution board) which has switches interposed in each branch circuit and is used for industrial works installations is shown in Fig. 50. This board is mounted within a sheet-steel protective case.

The distribution equipment and arrangements (see Figs 43 and 44) used in the power installations of industrial works take the form of the main distribution switchboards of various

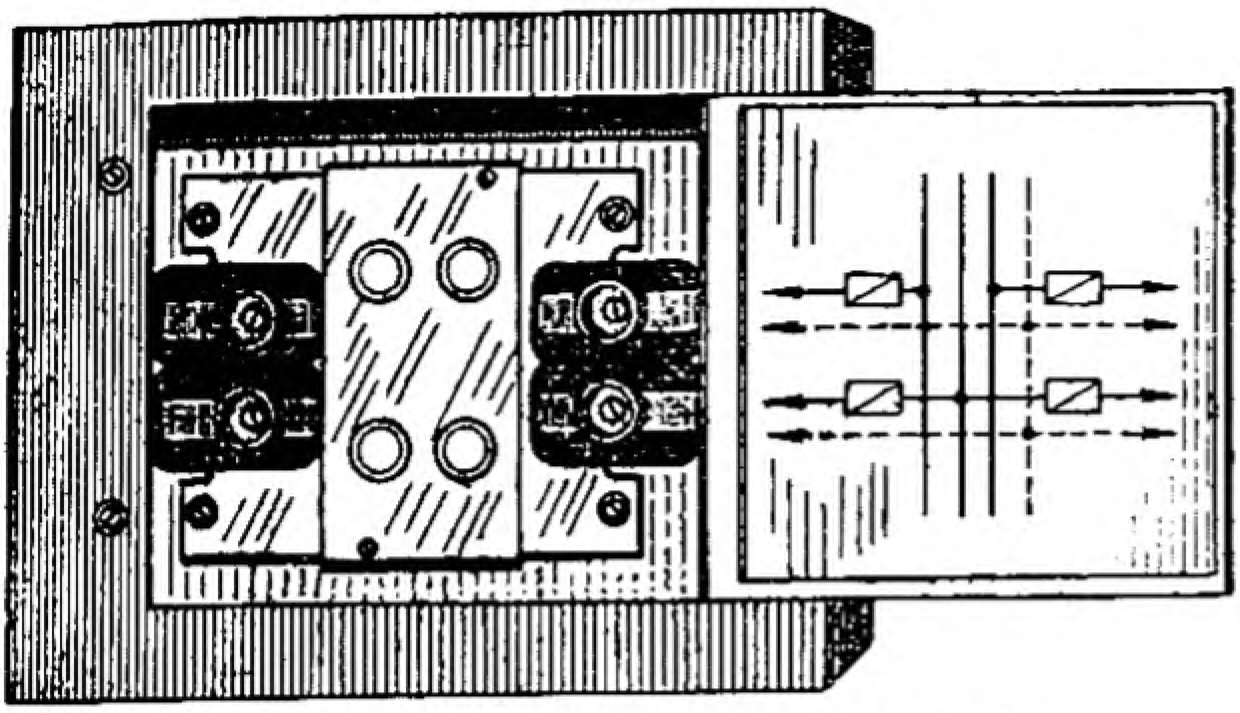


Fig. 48. Storey distribution board.

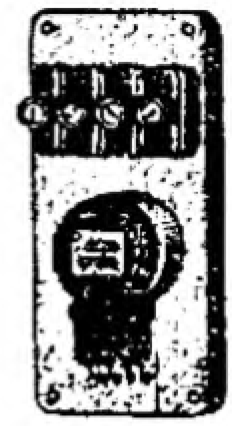


Fig. 49. Combined meter and fuse serviceboard for apartment-house flats.

construction installed in shop transformer substations, or main shop distribution centres and the form of local power panelboard cabinets for short-radius distribution within given shop areas.

Distribution switchboards may be of open, free-standing design (Fig. 51) for front operation and rear servicing, and all-around or three-side access, or of enclosed, wall-backed design (Fig. 52) for operation, servicing and access only from the front.

An open free-standing distribution switchboard comprises a framework (of angle iron) and a set of sheet-steel panels fixed to it. The indicating instruments (ammeters and voltmeters) are mounted on the front and top of each panel section. Below the indicating instruments, at a convenient height, are fitted lever-type operating

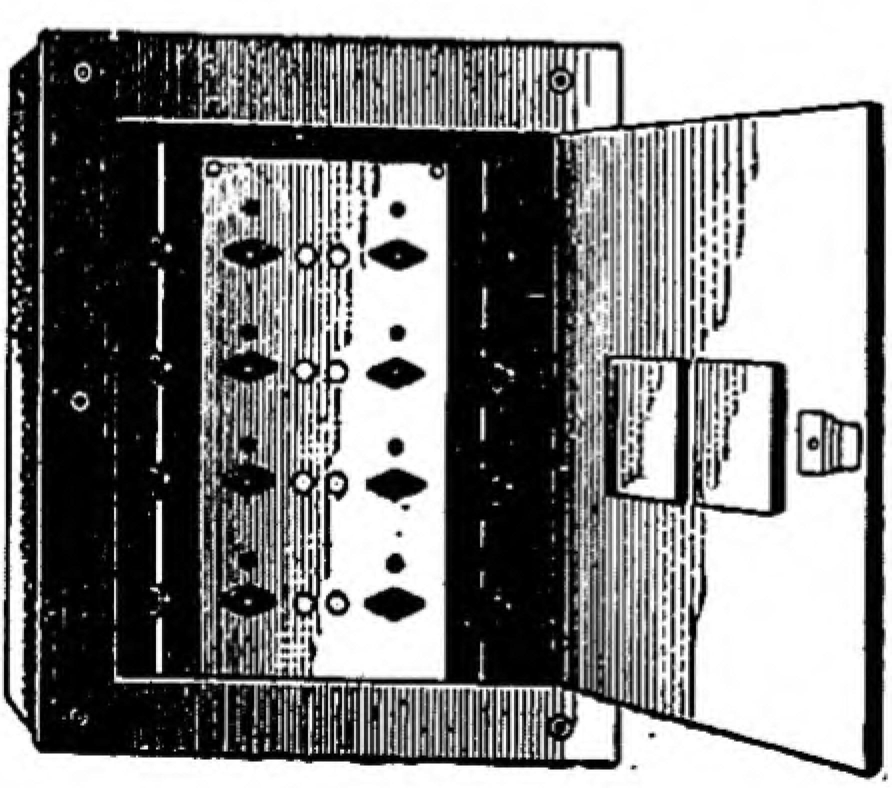


Fig. 50. Industrial-shop lighting distribution board.

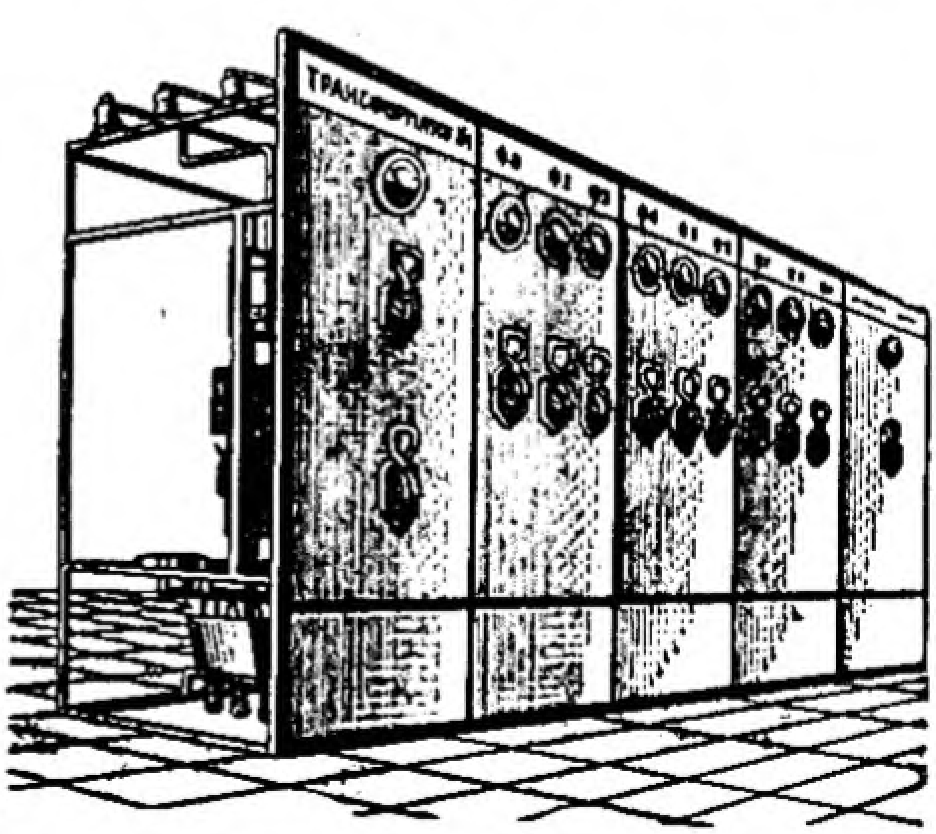


Fig. 51. Free-standing switchboard for front operation and rear servicing.

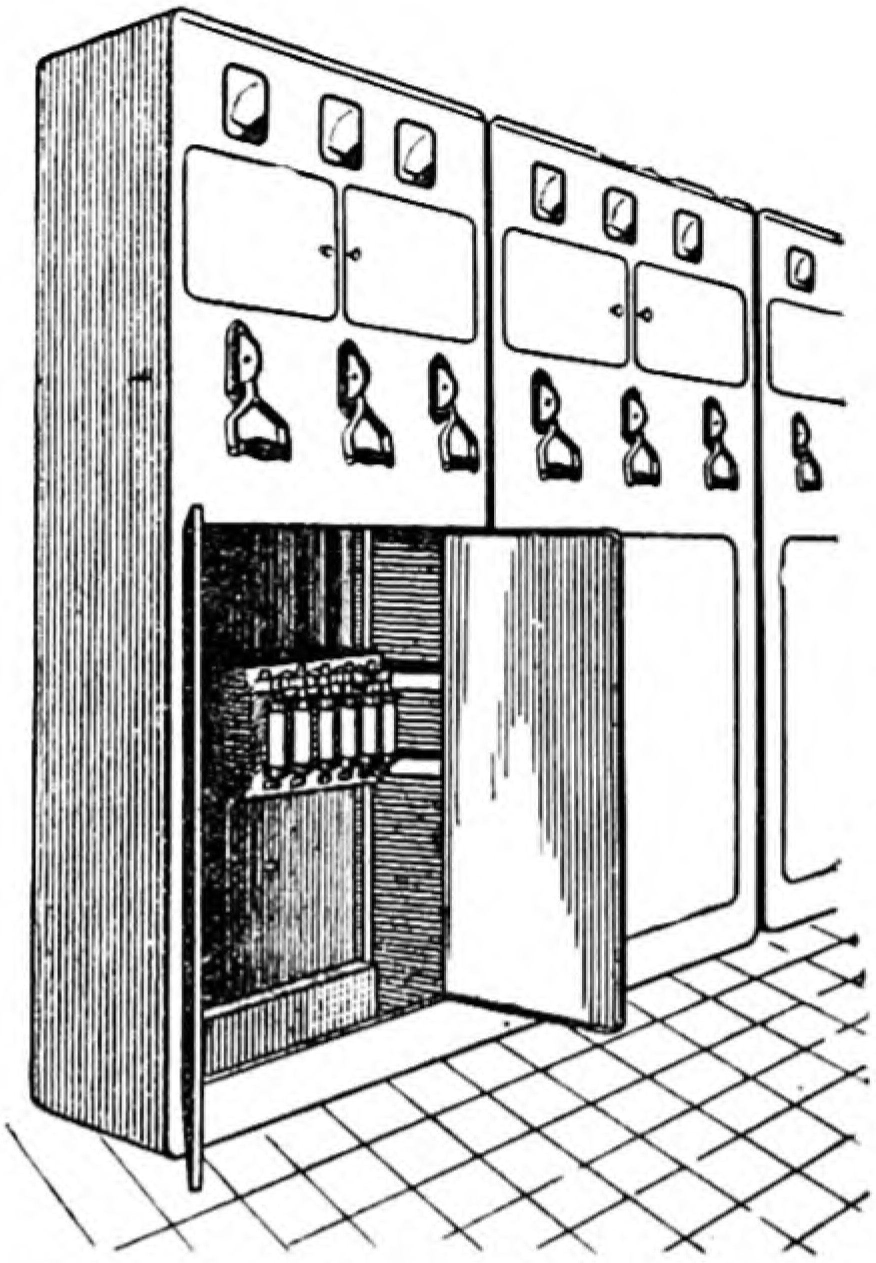


Fig. 52. Wall-backed distribution switchboard for front operation and servicing.

mechanisms used to open and close the knife switches.

Behind the panels and supported by the framework are the main bus-bars, the tap-off and interconnecting bus-bars, knife switches, fuses, instrument transformers and other live parts.

Fig. 53 shows one of the latest types of metal-clad distribution switchboards of unit-assembly design built up of standard panels in which are inserted removable preassembled units of control and protective equipment.

A power panelboard cabinet can be seen in Fig. 54. This distribution cabinet houses an angle-and-strip frame used for supporting the main bus-bars to which tubular type fuses *1* for protecting the outgoing lines are connected.

The main bus-bars receive supply through a common knife switch *2* mounted in the upper part of the cabinet, the supply feeder being run up to this switch for connection. Supported on the back side of the cabinet door are a set of spare fuse cases *3* and fuse-puller handle *4* used to remove and insert the fuse cases. In addition, the connection diagram of the cabinet is also shown on the inner surface of the door.

Such a power distribution cabinet is usually mounted in a shop by securing it to the floor above a cable raceway in which the distribution circuits are run. The cables and conduit pipes enter the cabinet through the open bottom, where they are fixed to cross member *5* of the cabinet frame.

5. Calculations for Determining Size of Conductors and Circuit Elements of Electrical Installations for Voltages up to 500 v

Calculation of Loads in Lighting Circuits

The load of a lighting branch circuit is the sum of the wattage ratings of all the lamps connected to the given circuit, and the load current of the circuit is determined by the formula

$$I = \frac{P}{U}$$

where I—load current, amperes;
P—total wattage of the lamps, watts;
U—rated voltage of the circuit, volts.

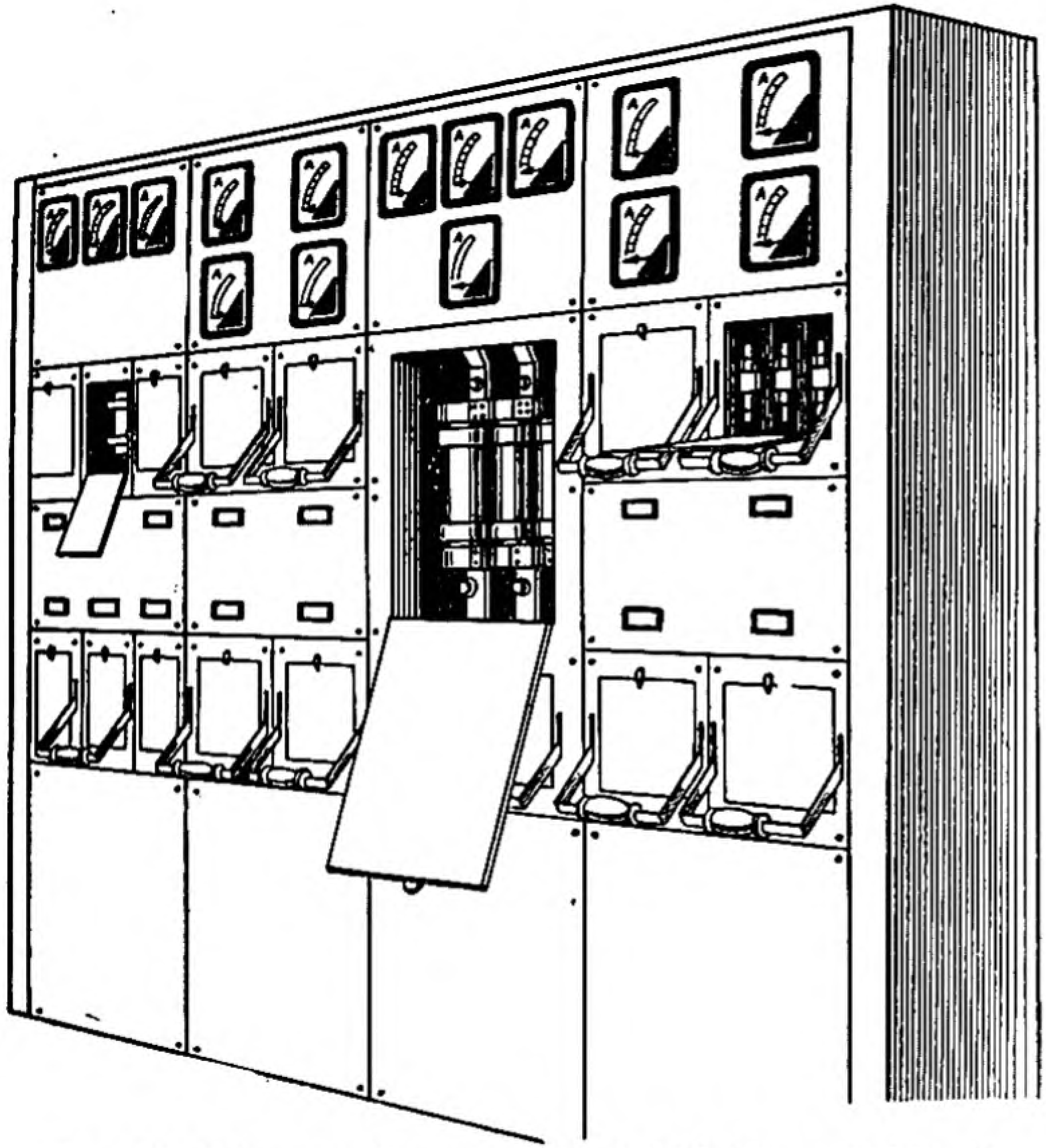


Fig. 53. Unit-assembly metal-clad distridution switchboarb

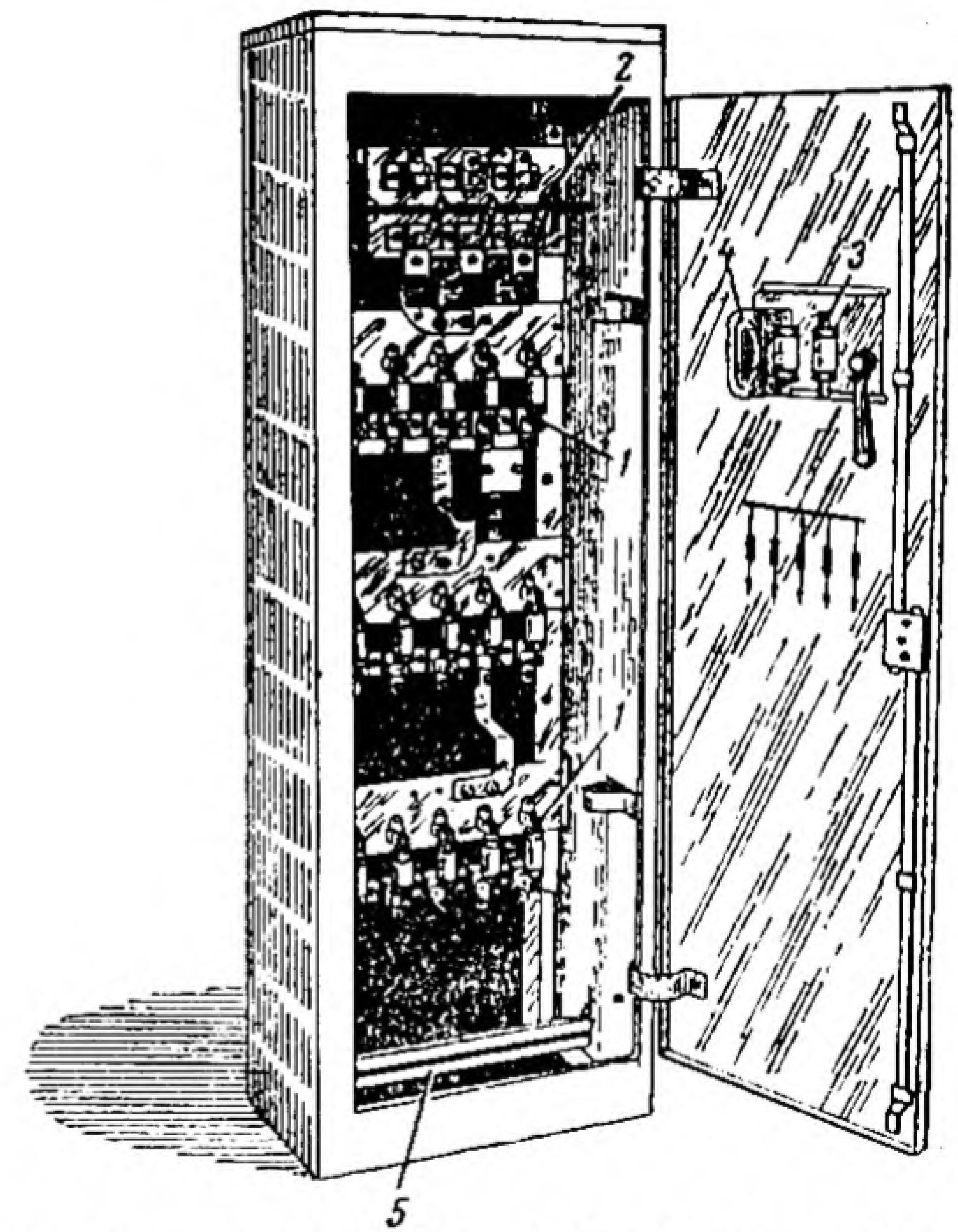


Fig. 54. Power panelboard distribution cabinet.

If, in addition to the lamps, domestic heating appliances (electric stoves, irons forming a combined light-appliance branch circuit) are also connected to the lighting branch circuit, it is assumed that, as a rule, they are not switched in at the same time. Therefore, to take into account the fact that all the devices in the circuit do not draw power simultaneously, a demand factor $k_{d.f.}$ is introduced in the above formula.

The formula for determining the load current of such a branch circuit then takes the following form:

$$I=\frac{P}{U}k_{d.f.}$$

The demand factor can be selected from special tables to suit each particular case (Table 6).

The load current of a lighting main is likewise calculated from the sum of the wattage ratings of all the electric devices connected to the circuits fed by the main and also with introduction of a demand factor in the corresponding formula.

The load current in two-wire mains is determined by the formula given above. For three-wire and four-wire mains, the load current is determined by the formula

$$I=\frac{P}{1.73U}k_{d.f.}$$

where P — total connected power capacity, watts;
U — line voltage, volts.

As stated above, the power P in the formulas given above must be expressed in watts. If the total power is expressed in kilowatts, then to express it in watts, the multiplier 1,000 must be introduced into the formula.

Example. Calculate the load current of a main feeding the lighting installation of a works storeroom department consisting of 30 lamps, each of 200 w. The circuit voltage is 220 volts and the main is three-phase three-wire.

Solution. Total power capacity of all the lamps is

$$P=200\times 30=6,000 \text{ w.}$$

Table 6

Demand Factors for Determining the Design Load (Maximum Demand) of Lighting Installations

Kind of installation	Demand factor
Lighting circuits in industrial buildings consisting of several large bays . .	0.95
Lighting circuits of industrial buildings consisting of a series of separate premises	0.85
Indoor lighting circuits of storeroom premises . . .	0.35
Branch circuits with lighting and domestic appliance loads	0.80
Individual groups of lighting fittings in any premises	1.00

The necessary demand factor, taken from Table 6, is 0.35. The load current will then be

$$I=\frac{Pk_{d.f.}}{1.73U}=\frac{6,000\times 0.35}{1.73\times 220}=5.6 \text{ a.}$$

Calculation of Load Current in Power Circuits

The load current in the branch circuit serving to supply an individual three-phase induction motor is calculated by the formula

$$I = \frac{P_{nom}\times 1,000}{1.73U\eta\cos\varphi}\ \text{amp}$$

where: P_{nom} — motor power rating, kw;
U — line voltage, v;
η — efficiency of the motor;
$\cos\varphi$ — power factor of the motor.

The values of the efficiency η and power factor $\cos\varphi$ are taken from the motor data plate or a catalogue.

For motors of low power rating, the product $\eta\cos\varphi$ can be taken equal to 0.7-0.8.

Example. Calculate the current in a three-phase a-c circuit run to a squirrel-cage induction motor rated for 10 kw. The voltage rating of the motor given on the motor data plate is 380 v.

The value of the product $\eta\cos\varphi$ is taken equal to 0.8.

Solution. The value of the load current is found by the formula

$$I = \frac{P_{nom}\times 1,000}{1.73U\eta\cos\varphi} = \frac{10\times 1,000}{1.73\times 380\times 0.8} = 19\ \text{a.}$$

The power load carried by a circuit feeding an a-c squirrel-cage induction motor, with accuracy sufficient for practical calculations, can be taken from Table 7.

To calculate the load current of power mains, the same formula by which the load current of lighting mains is calculated is used (see above). The demand factor can be taken from Table 8.

Example. Calculate the current in section *AB* of a three-phase power main supplying

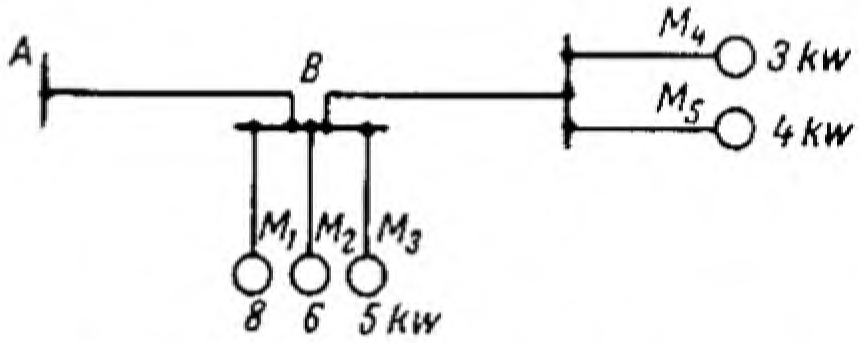


Fig. 55. Single-line diagram of a section of a three-phase power main.

current to two groups of motors in the shop of an industrial works. The supply voltage is 380 v. A single-line diagram of the installation showing the power ratings of the motors is given in Fig. 55.

Solution. The sum of the power ratings of motors M_1, M_2, M_3, M_4 and M_5 is

$$P_{nom} = 8+6+5+3+4 = 26\ \text{kw.}$$

For the known number of motors (5 units), the required value of the demand factor can be obtained from Table 8 (0.7 in this case).

The actual power load of the main is then determined by the formula

$$P = P_{nom}k_{d.f.} = 26\times 0.7 = 18.2\ \text{kw.}$$

The load current in section *AB* of the power main can be found from the formula

$$I = \frac{P\times 1,000}{1.73U\eta\cos\varphi}\ \text{a.}$$

Table 7

Data on A-C Three-Phase Squirrel-Cage Induction Motors

Power rating, kw	Power taken from circuit, kw	Efficiency	Starting current ratio, I_{start}/I_{rated}	Rated current, a — At rated voltage of: 220 v	380 v
For 3,000-rpm motors					
1.0	1.3	0.86	5.5	4.0	2.3
1.7	2.1	0.87	6.0	6.3	3.6
2.8	3.3	0.88	5.5	10.0	5.8
4.5	5.3	0.88	6.0	15.7	9.0
7.0	8.0	0.89	6.0	24.0	14.0
10.0	11.4	0.89	6.5	34.0	19.6
14.0	16.0	0.89	5.5	47.3	27.3
20.0	22.6	0.9	6.0	66.2	38.2
For 1,500-rpm motors					
0.6	0.8	0.77	5.0	2.8	1.6
1.0	1.3	0.80	5.5	4.0	2.3
1.7	2.1	0.83	5.5	6.7	3.9
2.8	3.4	0.85	6.0	10.4	6.0
4.5	5.3	0.86	6.0	16.1	9.3
7.0	8.0	0.87	6.5	24.3	14.0
10.0	11.5	0.88	5.0	34.4	20.0
14.0	16.0	0.88	5.0	47.5	27.4
20.0	22.5	0.89	5.0	66.5	38.4
For 1,000-rpm motors					
1.0	1.3	0.72	4.0	4.7	2.7
1.7	2.1	0.75	4.5	7.5	4.3
2.8	3.4	0.78	4.5	11.5	6.6
4.5	5.3	0.80	4.5	17.5	10.0
7.0	8.1	0.81	4.5	26.5	15.3
10.0	11.6	0.82	4.5	37.1	21.4
14.0	16.1	0.84	4.5	50.3	29.0
20.0	22.7	0.85	4.5	70.3	40.5
For 750-rpm motors					
4.5	5.4	0.76	4.5	18.7	10.8
7.0	8.3	0.78	4.5	28.0	16.0
10.0	11.6	0.80	4.0	38.7	22.3
14.0	16.1	0.81	4.0	52.3	30.2
20.0	22.8	0.82	4.5	73.5	42.5

Table 8

Demand Factors for Determining the Design Load (Maximum Load) of Power Installations

Nature of installation	Number of installed electric motors							
	2	3	4	5	6	7	8	10
Industrial-works machining departments, machine shops	1	0.90	0.80	0.70	0.60	0.55	0.50	0.44
Woodworking shops	1	0.85	0.75	0.65	0.55	0.50	0.45	0.40

Table 9

Permissible Current-Carrying Capacities of Wires and Cables with Rubber-Covered Copper Conductors at an Ambient Temperature of +25°C

Cross-sectional area of conductor, sq mm	Permissible current (amp) for								
	Open installed rubber-insulated wires ПРД (PRD), ШР (ShR), ПР (PR), ПРГ (PRG) and p. v. c.-insulated wires ПВ (PV), ПВГ (PVG), ППВ (PPV)	Rubber-insulated wires ПР (PR), ПРГ (PRG), ПРТО (PRTO) and p. v. c.-insulated wires ПВ (PV), ПВГ (PVG)					Steel-jacketed wire ТПРФ (TPRF), p. v. c.-sheathed cable ВРГ (VRG), lead-sheathed cable СРГ (SRG)		
		with total number of single-core wires in one conduit pipe			with one twin-core wire in conduit pipe	with one three-core wire in conduit pipe	single-core wire or cable	twin-core wire or cable	three-core wire or cable
		2	3	4					
0.75	13	—	—	—	—	—	—	—	—
1	15	14	13	12	13	12	—	—	—
1.5	$\boxed{20}$	17	15	14	16	13	20	17	17
2.5	27	24	22	22	22	19	27	24	22
4	36	34	31	27	28	24	36	34	31
6	46	41	37	35	35	30	46	45	37
10	$\boxed{70}$	60	55	45	50	45	70	60	50
16	90	75	70	65	70	60	90	80	65
25	$\boxed{125}$	100	90	80	90	75	125	100	85
35	150	120	110	100	110	90	150	125	105
50	$\boxed{190}$	165	150	135	140	120	190	155	130
70	240	200	185	165	175	155	240	190	160
95	290	245	225	200	215	190	290	—	—
120	340	280	255	230	260	220	340	—	—

Note: 1. Permissible currents for aluminium-conductor wires shall be taken at 77 per cent of permissible current for copper-conductor wires.

2. The figures enclosed in rectangles are useful for approximate sizing.

In performing an appoximate calculation, the value of $\eta \cos \varphi$ is taken equal to 0.8. The current in circuit section AB will then equal

$$I = \frac{18.2 \times 1{,}000}{1.73 \times 380 \times 0.8} \simeq 34 \text{ a.}$$

Selection of Wire and Cable Conductor Size According to Permissible Temperature Rise

From the basic laws of electricity it is known that when a current is passed through a conductor it heats it to some definite degree. In order to prevent the temperature from reaching a value dangerous for the safety of the conductor insulation, the Regulations (or acting Code) prescribe the maximum permissible current which each size of definite type of wire (and cable) can continuously carry. The values of these permissible current-carrying capacities are taken from special tables (see Table 9).

To protect the conductors from accidental overloads, for example, in the event of a short circuit, use is made of fuses or air circuit breakers. The current ratings of the fuse links to be inserted in fuses to protect different sizes of conductors can be taken from tables 10 and 11.

Table 10

Table for Selecting Fuse Links Inserted in Fuses for Lighting Circuits

Current rating of fuse link, a	Size of conductor (sq mm) — of wires — run exposed	Size of conductor (sq mm) — of wires — run in conduit pipe	Size of conductor (sq mm) — of cables
10	1.5	1.5	1.5
15	2.5	2.5	1.5
20	4	4	2.5
25	4	4	2.5
35	6	6	6
60	10	10	10
80	16	16	16
100	16	25	25
125	25	35	35
160	35	50	50
200	50	70	70

Table 11

Table for Selecting Fuse Links Inserted in Fuses for Power Circuits

Current rating of fuse link, a	Size of conductor (sq mm) in wires and cables — of branch circuits installed — open	of branch circuits installed — conduit in pipe	of branch circuits installed — in cable runs	of power mains installed — open	of power mains installed — in conduit pipe	of power mains installed — in cable runs
15	1.5	1	1.5	1.5	1.5	—
20	2.5	1	1.5	2.5	2.5	—
25	4	1.5	1.5	4	2.5	1.5
35	4	2.5	1.5	4	4	2.5
60	6	4	1.5	6	6	4
80	10	4	2.5	10	10	10
100	16	6	4	16	16	16
125	16	10	6	16	16	16
160	25	10	10	25	25	25
200	35	16	16	35	35	35

Procedure for Selecting Sizes of Conductors and Current Ratings of Fuse Links

The size of conductors and the current ratings of the fuse links used to protect them are selected in accordance with a definite procedure:

1) first determine the power load (in w or kw) to be carried by the conductor; after this—its design load current;

2) find the current rating of the fuse link which corresponds to the design load current of the conductor;

3) find the size of the conductor (from tables) using the current rating of the fuse link;

4) check the cross-sectional area (size) of the conductor found from the tables for sufficient current-carrying capacity without excessive temperature rise.

The loads to be carried by conductors are found as explained above.

In choosing the fuse-link current rating for a fuse, it is necessary to base the selection upon the three main conditions given below.

Condition one. The fuse-link current rating should be equal to or greater than the design load current (for any given section of a wired circuit).

For example, the design load current of a lighting circuit is 30 amperes. From the available nominal fuse-link current ratings (Table 10), we see that the closest nominal value is $I_{f.link} = 35$ a. Condition one is thereby satisfied since $I_{f.link} \geqslant I_{design}$ $(35 > 30)$.

Condition two. In a power circuit the fuse-link current rating should be equal to or greater than the value of the starting current divided by the factor 2.5, i. e.,

$$I_{f.link} \geqslant \frac{I_{start}}{2.5}.$$

For example, we know that the starting current $I_{start} = 125$ a. Using the above formula, we find

$$I_{f.link} = \frac{125}{2.5} = 50 \text{ a.}$$

From Table 11 we select a fuse link with the current rating $I_{f.link} = 60$ a since it is the nearest higher value. Condition two is thus satisfied, as $60 > 50$.

When severe starting conditions are met with, the starting current is divided by 1.5 instead of 2.5. The two above factors have been obtained by experiment.

When during the process of calculation it is found that the results obtained in observing conditions one and two are not equal, the largest of the two values is to be used. Such a method of fuse link selection is applied in order to prevent the link from being blown out by short-time flow of the starting current.

Condition three. Each fuse should blow out only when the fault occurs in the section it has been selected to protect. Thus, if a circuit supplies two motors,

one of which is protected by a 20-amp fuse and the other by a 10-amp fuse, the common line fuse should be determined by the following calculation:

$$I_{f.link\ common} = 20 + 10 = 30 \text{ a.}$$

On the basis of the above value, the nearest higher standard fuse-link rating taken from Table 11 is $I_{f.link\ common} = 35$ a.

In practice the current ratings of fuses arranged in sections following one another in a circuit should differ from each other by at least one step in current rating.

After the fuse-link current ratings have been found, we select the sizes of the conductors. How this is done is best illustrated by a practical example.

Example. Select the size of the conductors and the fuse-link current rating for a branch circuit used to feed an a-c 10-kw, 380-volt, 3,000-rpm three-phase squirrel-cage induction motor.

The circuit is wired with grade ПР-500 rubber-insulated wire installed in pipe conduit.

Solution. According to Table 7 the rated current of the motor is

$$I_{rated} = 19.6 \text{ a.}$$

To satisfy condition one, the nearest fuse-link current rating taken from Table 11 will be

$$I_{f.link} = 20 \text{ a}$$
$$(20 > 19.6).$$

To determine the starting current of a motor rated for 10 kw and 3,000 rpm, we first find its starting current ratio from Table 7, in this case equal to 6.5, whence

$$I_{start} = 6.5 \times I_{rated} = 6.5 \times 19.6 = 127 \text{ a.}$$

The calculated fuse-link current then is

$$I_{f.link} = \frac{I_{start}}{2.5} = \frac{127}{2.5} \simeq 50 \text{ a.}$$

The nearest standard current rating for the fuse link is 60 a (from Table 11). As the fuse link selected to satisfy condition one will be blown out during starting of the motor, it is not suitable for use.

Conductor size is likewise selected by using Table 11. With a fuse link of 60-amp rating inserted in the branch circuit, the size of the wires run to the motor in one conduit pipe should be 4 sq mm.

The wire size found above must now be checked to see that its load current is within the permissible current-carrying capacity given in Table 9 for three wires installed in one conduit pipe. The table shows that the permissible current for wires of 4 sq mm size is equal to 31 a.

Since the design load current is 19.6 a, the selected size of the wire satisfies the necessary conditions as

$$I_{perm} = 31 \text{ a}; \ I_{design} = 19.6 \text{ a}$$
$$(\text{i. e., } I_{perm} > I_{design}).$$

Calculation of Conductor Size According to Voltage Drop

For simplified calculation of conductor sizes according to voltage drop, the following formula can be used

$$s = \frac{M}{C \Delta U}$$

where C — a factor depending upon the voltage of the circuit and the material of the conductors (their conductance);

ΔU — permissible voltage drop in per cent*;

$M = Pl$ — the sum of the products obtained by multiplying each load by the length of the circuit section through which it receives supply, this sum being termed the load-moment sum.

Some of the values of factor C are listed in Table 12.

In practice the load-moment sum can be replaced in many cases by a single load moment which takes the form of a product equal to the sum of all the loads multiplied by the so-called equivalent length of the circuit.

The equivalent length of the line is taken equal to the distance from the beginning of the circuit to the centre of the individual concentrated loads.

* In practice the voltage drop ΔU, from transformer substation to furthermost power receiver, is taken equal to from 4 to 5 per cent.

Table 12

Several Values of Factor C

Voltage of circuit, v	Circuit arrangement	Value of C for copper conductors	Value of C for aluminium conductors
127 220	Single-phase	4.6 14.0	2.8 8.3
220/127 380/220	Three-phase, four-wire	28.0 83.0	17.0 50.0

Thus, for example, a circuit diagram (Fig. 56) is drawn to show the values of the different loads and their corresponding circuit lengths. The separate loads are then replaced by one total load:

$$P = P_1 + P_2 + P_3 = 300 + 300 + + 300 = 900 \text{ w.}$$

The total voltage drop will not change if this load is taken off at the centre of section *ac*, i. e., at point *b*. In this case the equivalent length, the distance from supply source *0* to point *b*, is equal to 20 metres.

The load moment in this case will then be

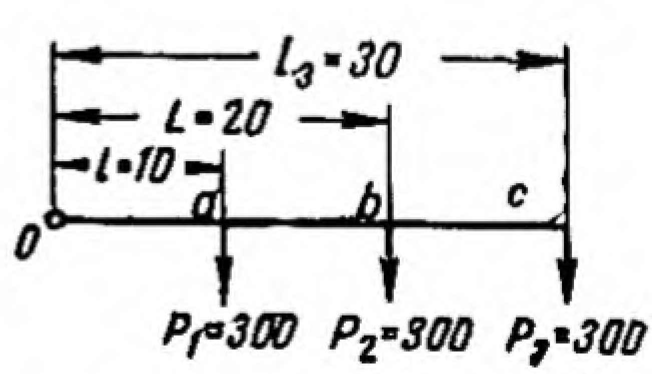


Fig. 56. Diagram showing power circuit with several loads.

$M = Pl = 900 \times 20 = 18{,}000$ watt-metres.

Example. It is necessary to install a three-phase four-wire main with copper wires to supply a shop lighting installation for a load equal to 15 kw. The circuit voltage is 380/220 volts, and the distance from one shop transformer substation to another is 250 m.

Determine the size of the wires in the main when the permissible voltage drop $\Delta U = 2$ per cent.

Solution:

$$s = \frac{M}{C \, \Delta U}.$$

Find the value of factor C in Table 12. In this case, since copper wires are to be used and the circuit voltage is 380/220, $C = 83$.

Then

$$s = \frac{M}{C \, \Delta U} = \frac{15 \times 250}{83 \times 2} = 22.5 \text{ sq mm}.$$

The closest standard conductor size is 25 mm².

Graphical Method for Selecting Size of Wires and Cables

For practical wiring, the calculations for the size of wires can be carried out by using the graphs suggested by N. N. Lebedev (Fig. 57).

First to be calculated is the load moment Pl. This value is then sought on the vertical scale for the corresponding circuit voltage. From this point a horizontal line is laid off to intersection with the line giving the necessary per cent voltage drop ΔU.

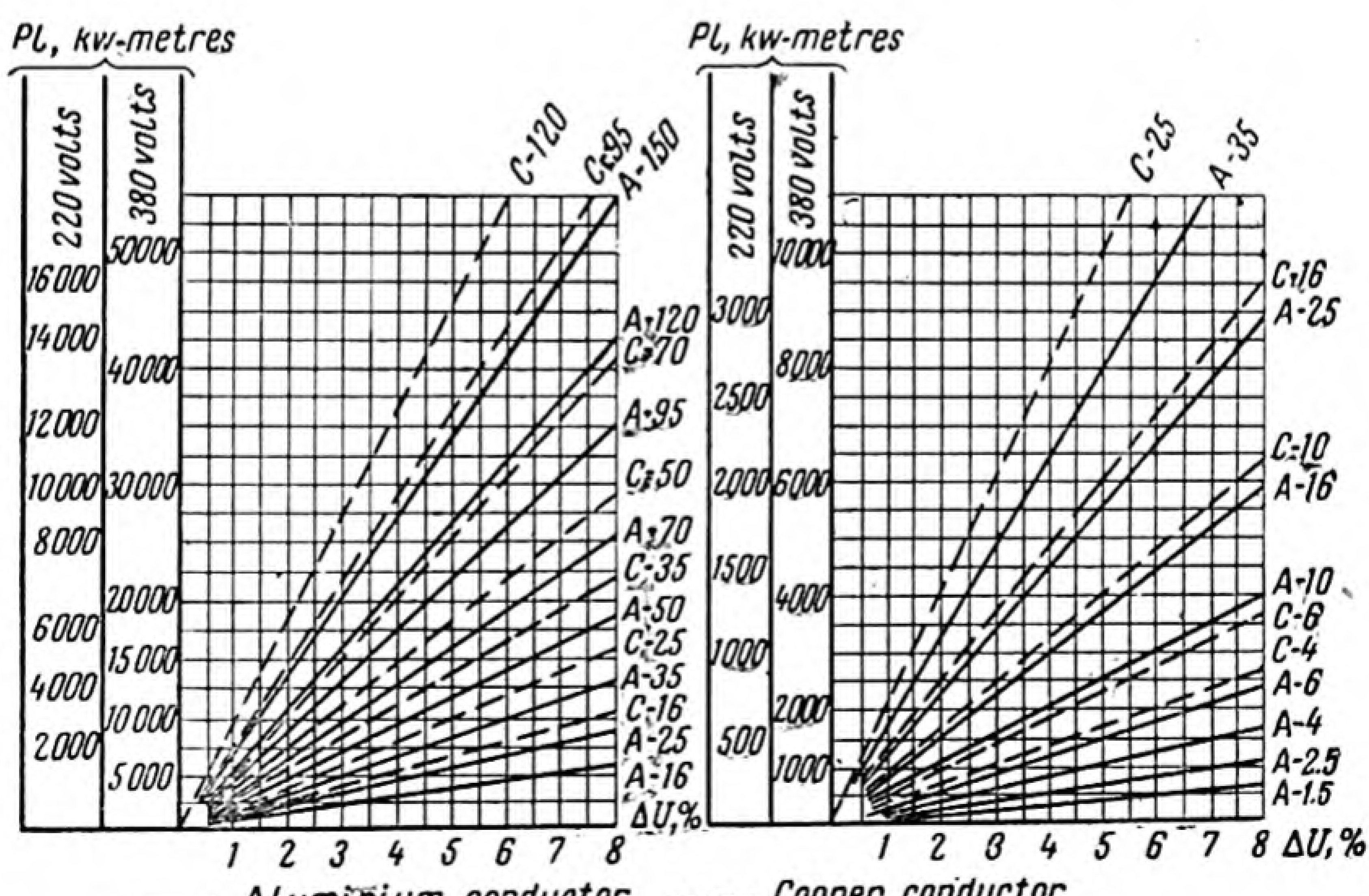


Fig. 57. Graphs for selecting wire and cable conductors for various loads.

Each conductor represented on the graph has its size indicated at the end of the ray line. These lines have been drawn to give the sizes of both copper and aluminium conductors.

After a conductor size has been obtained from the graph, it must be checked for permissible current-carrying capacity (Table 9).

Example. Select the size of copper wires for an exposed three-phase supply main used to carry a 60-kw load for a shop lighting circuit. The circuit voltage is 380 v, the permissible voltage drop ΔU is 5 per cent, and the distance from the works transformer substation to the load is 100 m.

Solution. The load moment is

$$M = Pl = 60 \times 100 = 6{,}000 \text{ kilowatt-metres.}$$

After finding the point on the vertical scale having the same value as that calculated above, project this point horizontally until it reaches the vertical division representing a voltage drop of 5 per cent.

At the end of the ray passing through this point of intersection we find the necessary size of the copper wire to be equal to 16 sq mm.

To check the size of the wire determined above for permissible current-carrying capacity, we now calculate the load current in the main:

$$I = \frac{P}{1.73\ U} = \frac{60 \times 1{,}000}{1.73 \times 380} = 90 \text{ a.}$$

From Table 9 we find that copper wires of 16 sq mm size installed exposed have a permissible current-carrying capacity of 90 a.

It should be noted that the sizes of conductors for short branch runs (service entrance runs, branch lines to motors, etc.) can be selected from tables of permissible current-carrying capacity.

The Elements of Designs for Electrical Installations with Voltages up to 500 Volts

The designs for an electrical installation include a set of working drawings, an explanatory note giving the design calculations for the selected wire and cable sizes and data on the selected apparatus, fittings and accessories, and also an estimate of the cost of the project.

The most important part of the designs (project) for an electrical installation is the set of working drawings according to which installation is to be carried out.

Sets of working drawings consist of plans for each floor of the buildings to be wired, layout plans and diagrams of the mains and separate detail working drawings for various particular assemblies of the given installation.

Floor plans are usually drawn to scales of 1 : 50, 1 : 100 and 1 : 200, with thin lines used to show the outlines of structural parts and main units of technical equipment; lines of slightly

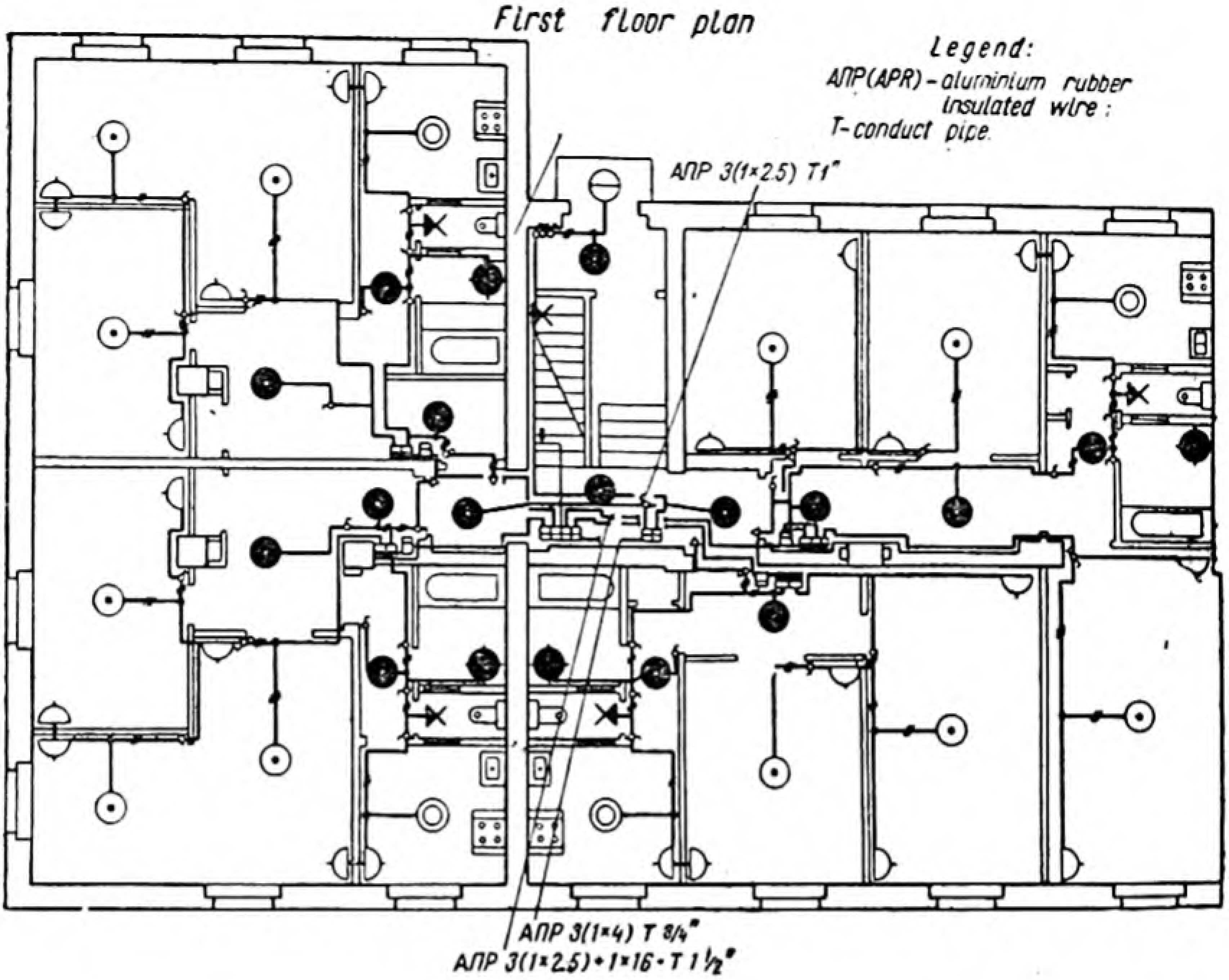


Fig. 58. Part of a floor plan for a lighting installation.

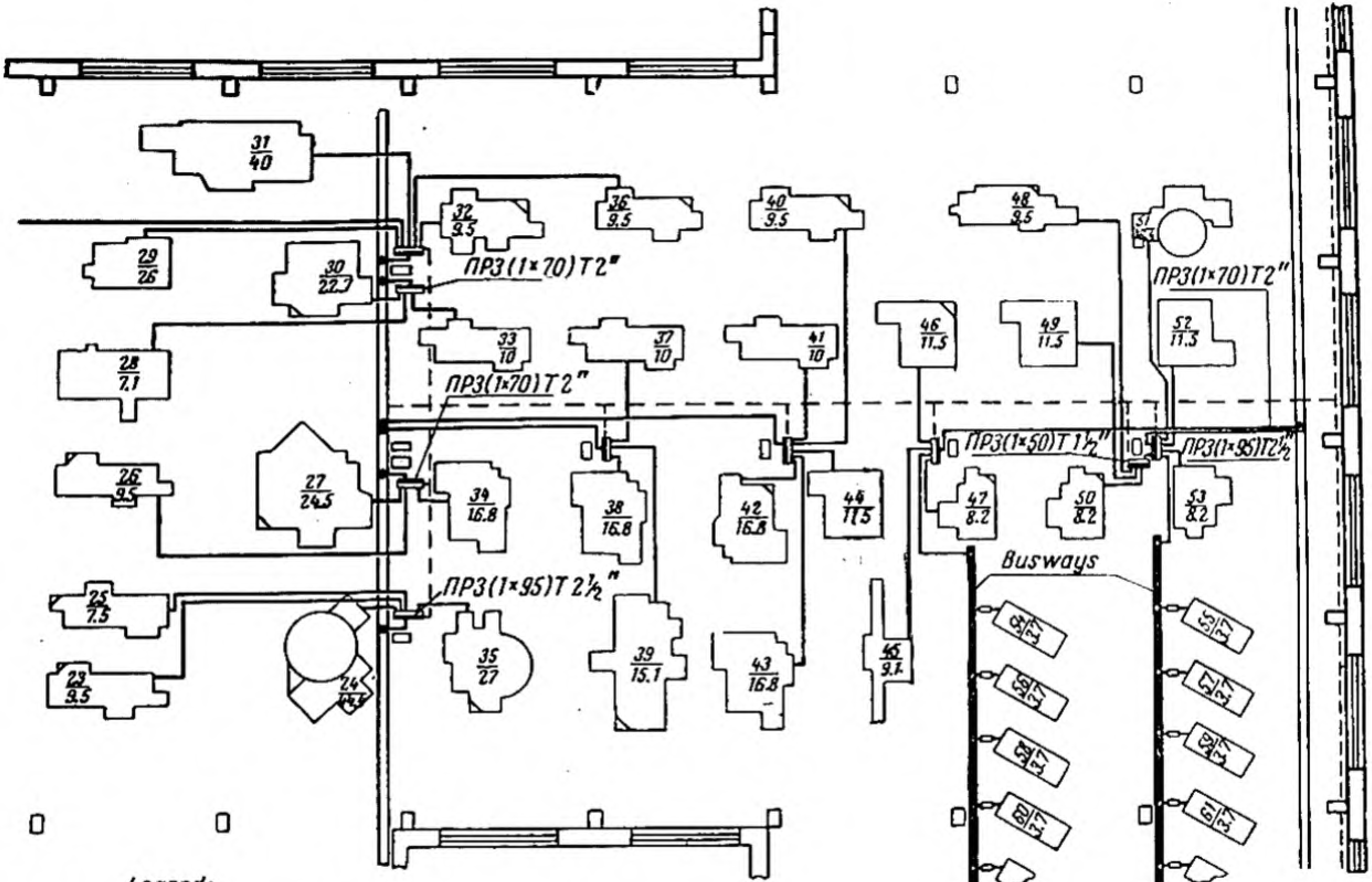
greater thickness are used to show the elements of the electrical installation—the lighting fittings, fuseboards, supply mains and branch circuits, the units of electric power equipment and the power circuits.

The supply-mains circuit drawing shows the principal lighting and power mains from the service entrance up to the distribution switchboards and panelboards.

The drawings for electrical installations should show precisely what types of lighting fittings, switchgear, motors and starting devices must be installed, should indicate the sizes of all the wires and cables in all the circuit sections and also prescribe how the wire and cables must be installed. Requirements and directions common for all parts of a given drawing are usually provided in the form of a "technical requirements" list on the drawing.

Drawings for lighting and power installations, in the majority of cases, are drawn separately for each kind of installation.

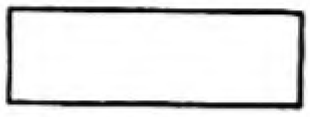
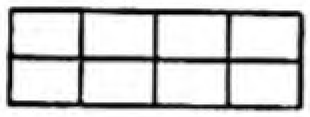
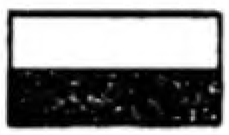
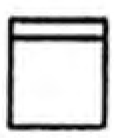
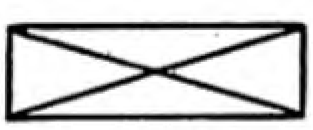
Parts of floor plan drawings for lighting and power installations can be seen in Figs 58 and 59.

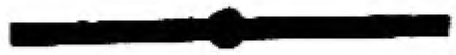
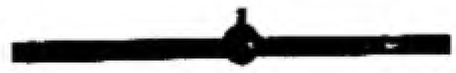
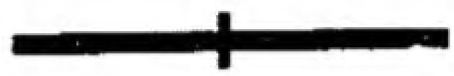
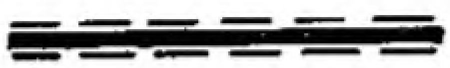
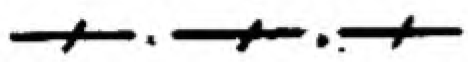
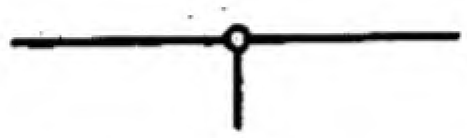
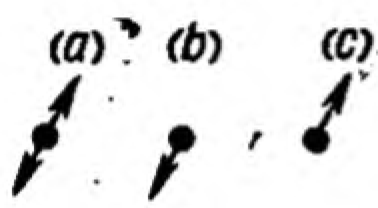
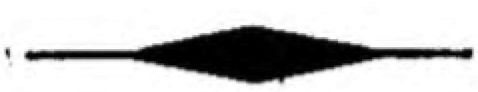
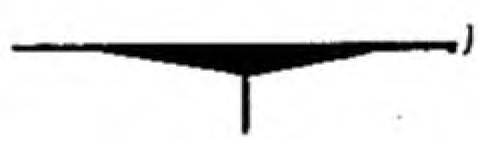
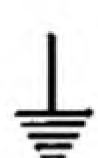


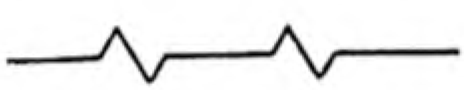
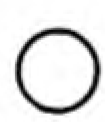
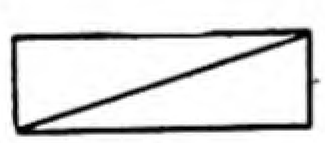
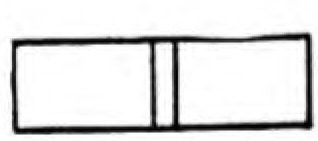
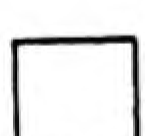
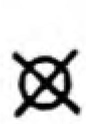
Legend:
ПР (PR) - copper-conductor rubber-insulated wire
T - conduit pipe

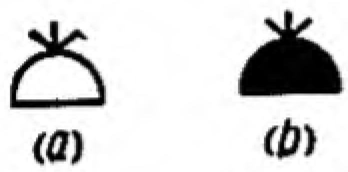
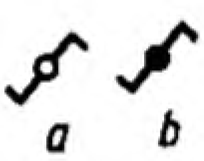
Fig. 59. Part of a floor plan for a power installation.

Graphic Symbols for Electrical Equipment and Wiring for Use on Electrical Plans (According to U.S.S.R. State Standard)

	Transformer substation
	Switchboard, control desk, control cabinet
	Switchboard, distribution panelboard, distribution centre
	Distribution cabinet (power, lighting)
$\frac{A}{B}$	Marking for power distribution cabinets: *A*—identification marking of cabinet on plan, *B*—connected power capacity, kw (kva)
	Meter
	Working lighting branch-circuit fuseboard
	Emergency lighting branch-circuit fuseboard
$A\frac{Б}{В}Г$	Marking for distribution cabinets and branch-circuit fuseboards: *A*—identification marking of cabinet or fuseboard on plan, *Б*—connected power capacity, kw, *В*—per cent voltage drop, *Г*—type designation of cabinet or fuseboard
	Power circuits, lighting circuits for a-c voltages up to 500 v
(a) (b)	Working lighting circuits: *a*—only on separate lighting circuit drawings, *b*—for combined lighting and power circuit drawings
(a) (b) 	Emergency lighting circuits: *a*—only for separate lighting circuit drawings, *b*—for combined lighting and power circuit drawings
	Circuits with a voltage of 36 volts and lower

	Enclosed busways mounted on post supports
	Enclosed busways, suspension supported
	Enclosed busways, bracket supported
	Enclosed busways, installed under floor
	Earthing circuit
	Earthing electrodes
	Tee-off
	*a*—circuit run upward and downward, *b*—circuit run downward, *c*—circuit run upward
	Cable joint boxes
	Cable tee-off boxes
	Cable sealing end (pothead)
	Earthing point
1—A; 2—B; 3—C; O	Phase and neutral markings
AB; AC; BC	Lines tapped from two line conductors
AO; BO; CO	Lines tapped from a line and the neutral conductor
	Cable duct, trough, or raceway
	Cable trench

Шш (Sh sh)	Busway, plug-in type
Шб (Sh b)	Busway, bolted tap-off system
Тр (Tr)	Trolley conductor line
Т	Wiring installed in pipe conduit
П (P)	Concealed wiring installed in semihard rubber tubing
С	Concealed wiring installed in glass tubing
	Surface-installed pipe conduit
	Surface-installed cable
СГ 1(3×70) Т2" АПР 3(1×70) И АПР2[3(1×95)]Т2 1/2"	Abbreviations and markings used for making runs of wiring: grade of wire or cable, number of circuits, number of conductors, size of conductors, type of wiring (the figure after the letter T, which means pipe conduit, indicates the inside diameter of conduit pipe, letter И [I] indicates wiring installed on insulators)
	Induction electric motor
	Fuse box (in a circuit diagram indicates a fuse)
	Box with a knife switch
	Starter
	Wall-mounted lampholder
	Pendent lampholder

×	Ceiling-mounted lampholder
	Plug sockets: *a*—normal type, *b*—hermetic type
	Two-pole plug sockets with third earthing contact: *a*—normal (general-purpose) type, *b*—hermetic type
	Three-pole plug sockets with fourth earthing contact: *a*—normal (general-purpose) type, *b*—hermetic type
	Normal (general-purpose) lighting switches: *a*—single-pole, *b*—two-pole, *c*—three-pole
	Hermetic type lighting switches: *a*—single-pole, *b*—two-pole, *c*—three-pole
	Multi-way lighting switches: *a*—normal (general-purpose) type, *b*—hermetic type
1) $a \times b$ 2) $\frac{a}{b}$	Design characteristics of a lighting point: 1) *a*—number of lamps, *b*—lamp wattage; 2) *a*—lamp wattage, *b*—height of installation, m

Note: See Table 5 for the graphic symbols of various types of lighting fittings.

Part Two

INSTALLATION OF WIRING AND BUSWAYS FOR CONSUMER ELECTRIC CIRCUITS WITH VOLTAGES UP TO 500 VOLTS

Chapter III
INSTALLATION OF WIRING

1. Main Operations in Installation of Wiring

Electrical wiring is installed in a definite sequence and is subdivided into the following general work operations:

laying-out and marking-off work during which are laid out and marked off: all the places where the units of equipment are to be installed, all the runs for the wiring to be put in, and all the places where the wiring must be run through walls and floor structures;

preparatory work (or roughing-in)—the operations during which through and blind holes are driven, grooves and deep recesses are cut, fixing parts and insulating supports are anchored in place, conduit pipes are fitted and installed, and tubing used for installation of the wiring is put in;

installation of the wiring—the work in actual installation of the wires and cables, and the making of the necessary joints and tee-offs in them;

mounting of the lighting fittings and switching apparatus—the work of fitting the separate lighting units with the internal hook-up wiring, of mounting the lighting units and connecting them to the lines of wiring, of fixing units of apparatus in their working position, and of drawing-in and connection of the wiring to the terminals of the various units of apparatus.

2. Tools, Appliances and Mechanisms Used for Performing Electrical Wiring Work

To put in electrical wiring, sets of installer's tools, appliances and mechanisms are required.

Tools are, as a rule, in the personal use of each installer.

Appliances and mechanisms are generally assigned to separate crews and even to all the crews working on a given site. They are stored in the site work shop or tool room, from which they are handed out to the installers whenever necessary. In accordance with the character of the work performed with them,

tools, appliances and mechanisms are subdivided into separate groups.

Laying-out and Marking-off Tools and Appliances

Tape measure. A dense oil-cloth or steel tape enclosed in a metal, moulded plastic or leather case. Installers use 5- and 10-metre tape measures mainly for measuring off general dimensions.

Marking-off cord reel. Consists of a moulded-plastic case containing a reeled synthetic-fibre cord of 2 to 3 mm diameter and 5 to 10 metre length.

Where the cord is pulled out for use, the case is provided with a gland in the form of a gauze bag filled with a powdered colouring pigment (Prussian blue, chalk, ochre). As the cord is pulled out of the case and passes through the colouring powder, it becomes coated with the colour and can be used for beating-off marking lines on required surfaces.

Marking-off stick. A wooden stick 2.5 to 3 metres long fitted with a sharpened metal tip, a cord and a plumb bob. The marking-off stick is used to mark off horizontal and vertical lines on walls and ceilings.

Marking-off dividers. A tool used to mark off direcly from the floor the intervals between supports for wiring.

Places where units of apparatus are to be mounted, especially if the units have identical dimensions and are used in large

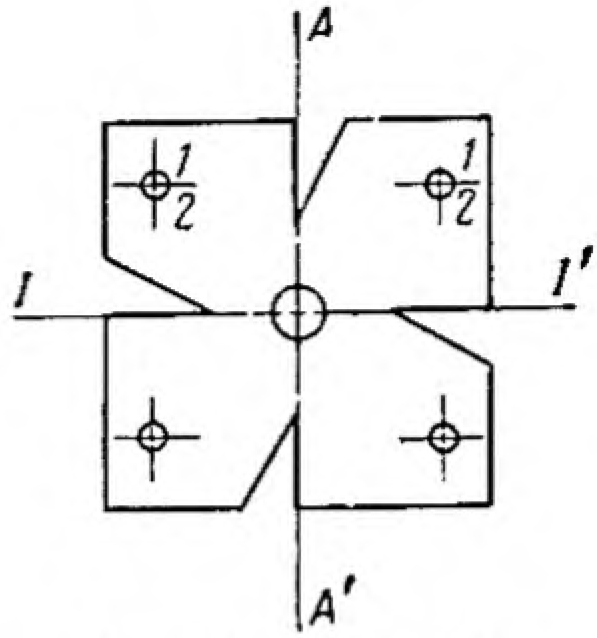


Fig. 60. Template:
I-I'—horizontal axis,
A-A'—vertical axis.

numbers, are best marked off with the aid of marking templates. (Fig. 60).

Templates are prepared directly on the site from plywood or roofing steel.

Marking-off on cornices is generally done with the aid of a special flexible tape appliance.

In performing marking-off wide use is made of straight rules and of folding, metal or wooden rules. Some of the tools and appliances used for marking-off are shown in Figs 61 and 62.

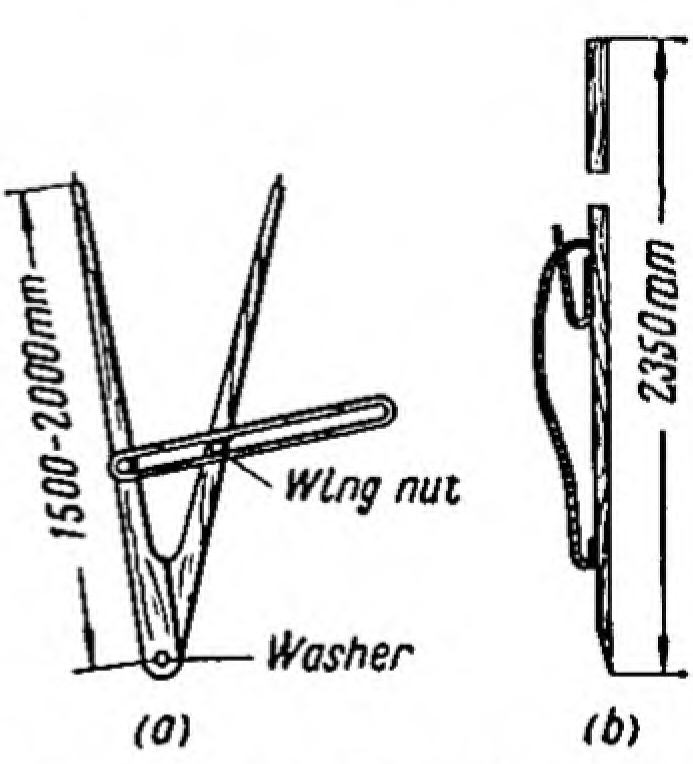


Fig. 61. Marking-off tools:
a—dividers, b—marking-off stick.

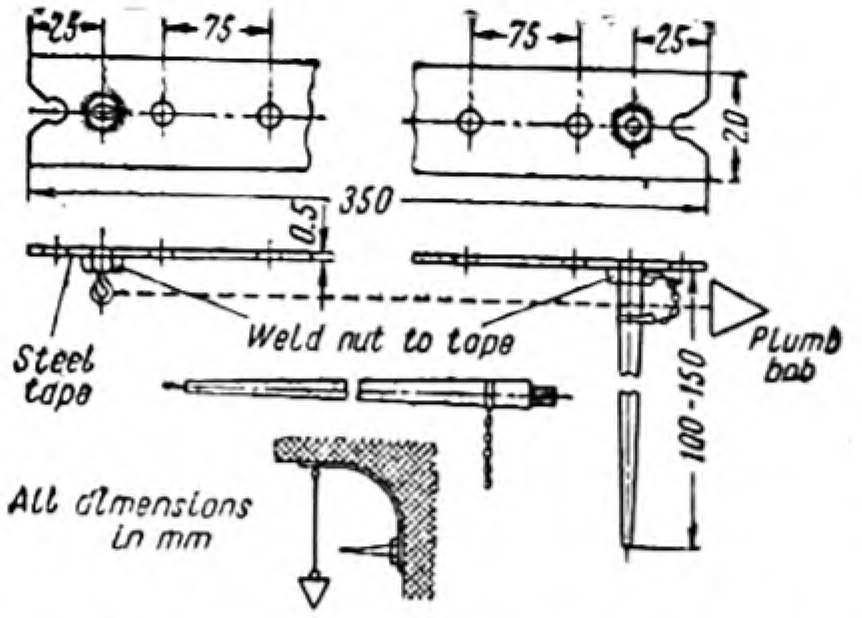


Fig. 62. Appliance used for marking-off on cornices.

Appliances and Hand Tools for Roughing-in

Electric hand drill (Fig. 63). An electric-powered drill with a power rating of about 0.4 kw and a spindle speed of 1,200 rpm.

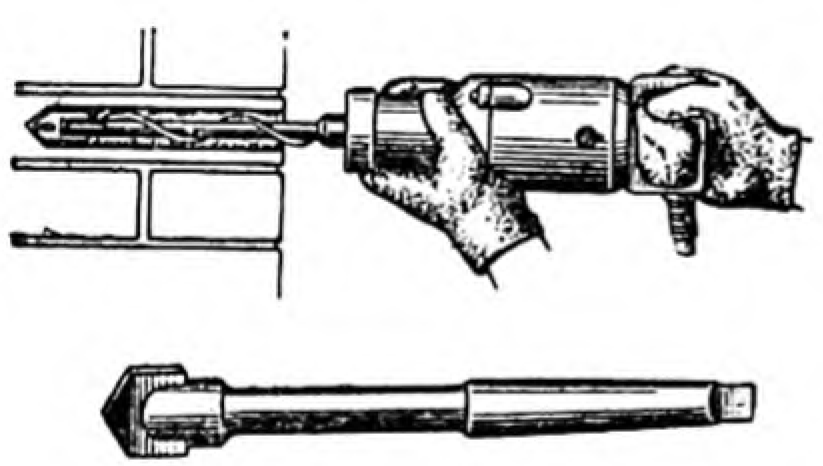


Fig. 63. Electric hand drill with drill bit having cemented-carbide tip.

Drilling with such a tool is done by using drill bits tipped with sintered-carbon inserts. Hand drills fitted with such bits can drive holes in brickwork, concrete and like materials.

Through holes in walls and floor structures are drilled with the aid of a support leg of special construction (Fig. 64).

The main part of this appliance is the electric hand drill secured in its special moving-frame member by means of which the possibility of drilling at different angles of inclination is provided.

Electric hand milling groover. An electric-powered hand tool designed to cut grooves in cast gypsum partitions. The cutting part of this tool is a sheet-steel disk on which plates of grade BK-8 (VK-8) cemented carbide are spot welded to form the cutter teeth (Fig. 65).

Pneumatic hammer (Fig. 66). A hand tool serving to drive holes and cut grooves in brickwork, concrete and like structural elements of buildings.

Air-powered tools are generally supplied with compressed air from a special portable compressor unit.

Today the type СМП-1 powder-actuated stud gun is the kind of tool used to directly drive fixing studs and dowels into brickwork and concrete. Its action depends upon the forces developed when a charge of powder is fired in the gun. A general view of this stud driver is given in Fig. 67.

The stud driver set includes a single-shot pistol and its breech mechanism, accessories, and sets of powder cartridges, fixing studs and dowels.

For driving different sizes of fixing parts, the stud driver set includes, in addition to the main 12-mm diameter barrel, a second interchangeable 8-mm diameter barrel. The weight of this stud driver is 3 kg.

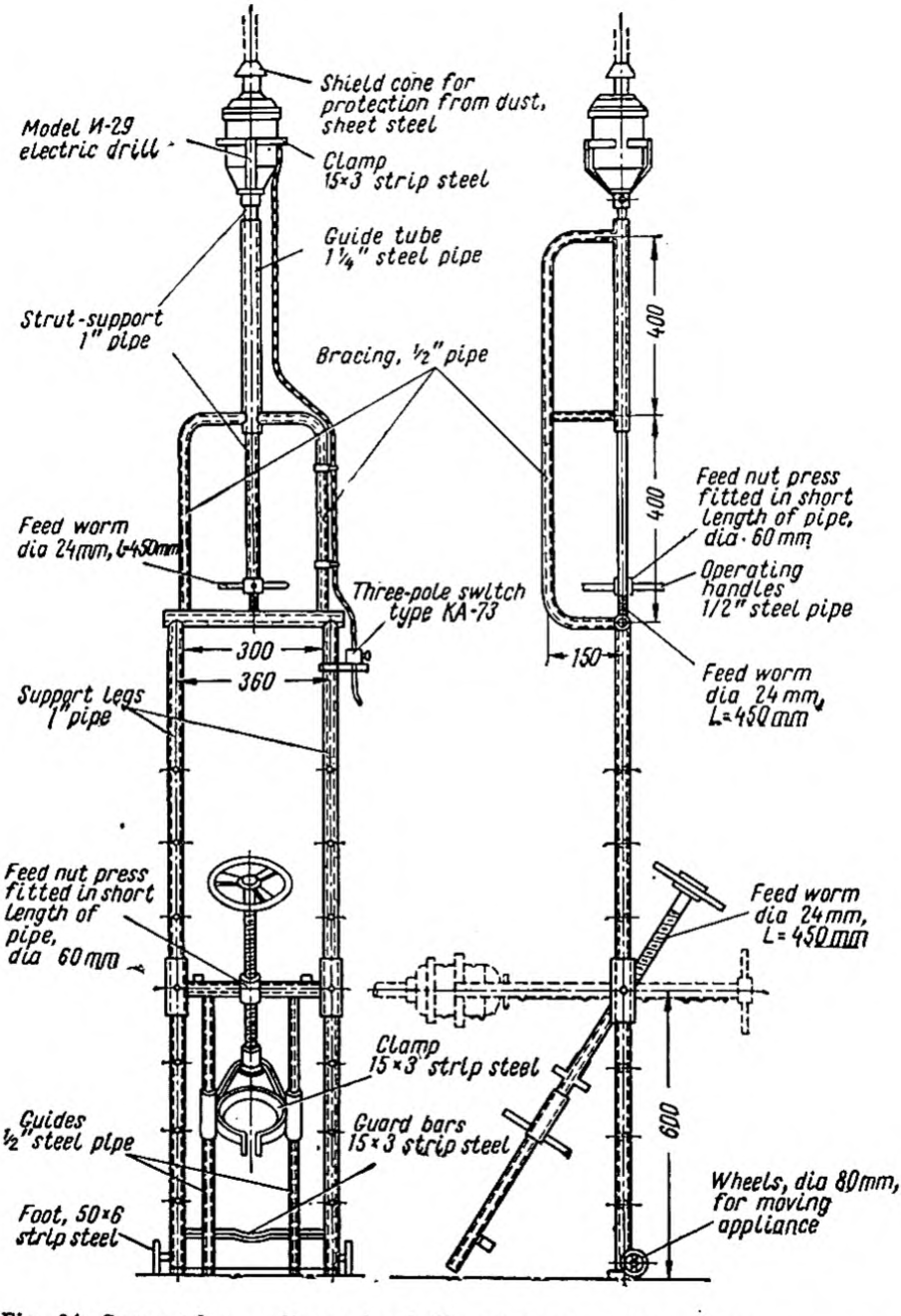


Fig. 64. Support-leg appliance for drilling holes in walls and floor structures.

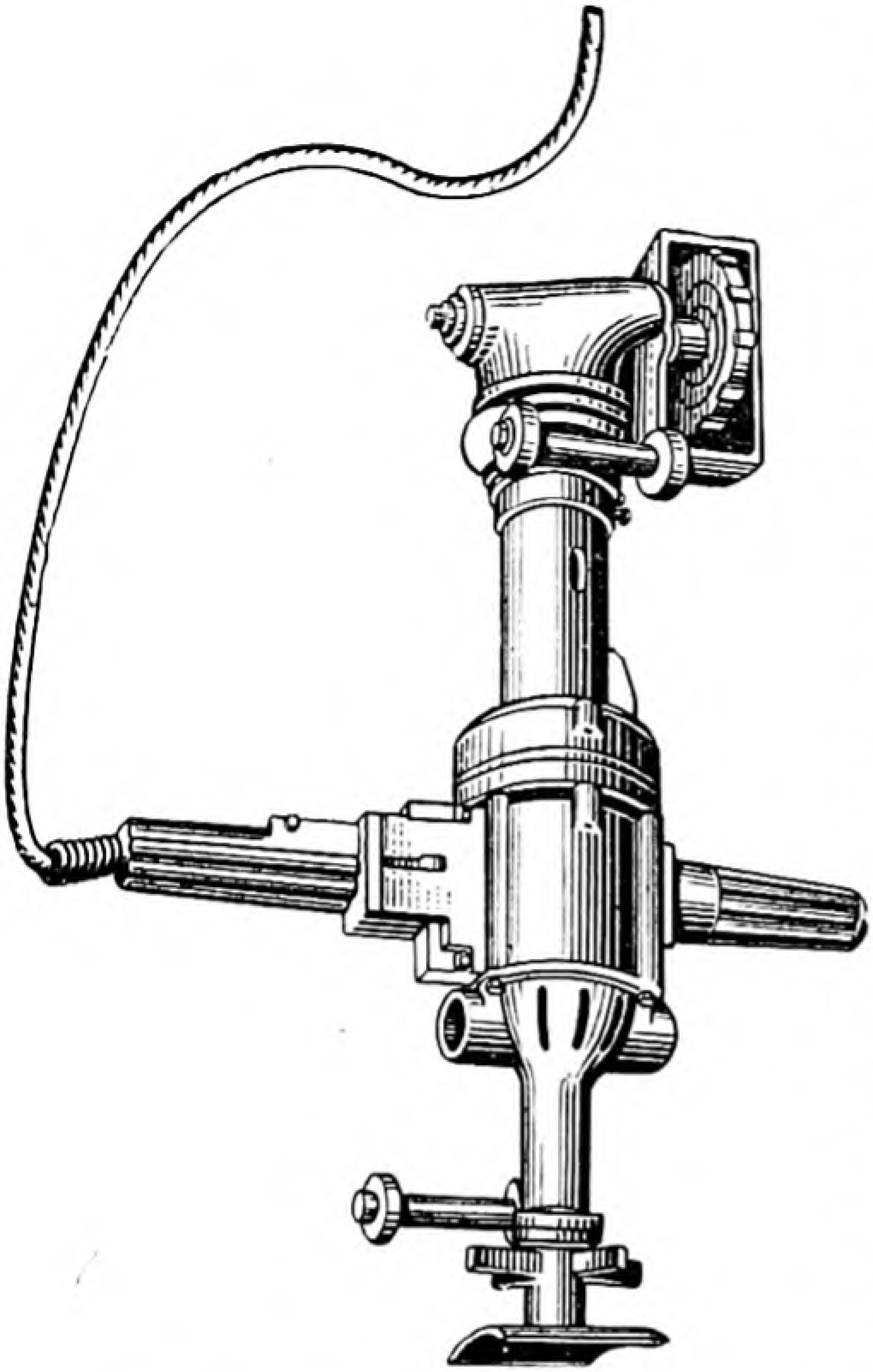


Fig. 65. Electric milling groover.

To do preparatory, or roughing-in work, a series of hand tools are used. They are tools such as hammers, cold chisels, cape chisels, rod chisels (long-length cold chisels), triple-fluted drift pins, star drills.

Star drills are made from 1/2" to 1 $^1/_2$" steel pipe in lengths of from 500 to 1,500 mm. The cutting fend is dressed to form a set ob saw-shaped teeth which are susequently case-hardened, and the striking end (head) is made in the form of a solid piece of steel machined to a taper at the end and welded to the pipe.

Star or hollow drift drills are used for driving through holes in brick walls. The striking tool for driving holes with these drills is either an ordinary hammer or a sledge hammer.

To do preparatory work it is also necessary to have a rubber gypsum mixing bowl for making up cementing mortars, an installer's awl, screwdrivers, pliers, wire cutters, spanners and other tools (Fig. 68).

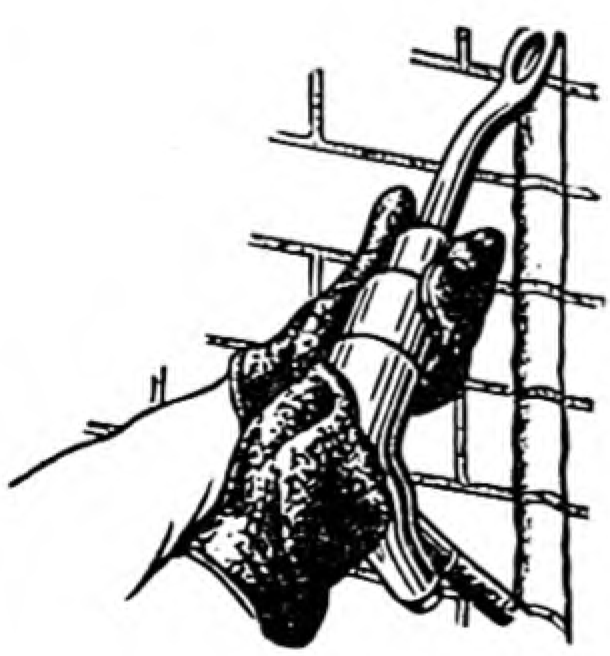


Fig. 66. Pneumatic hammer fitted with a chisel for cutting grooves.

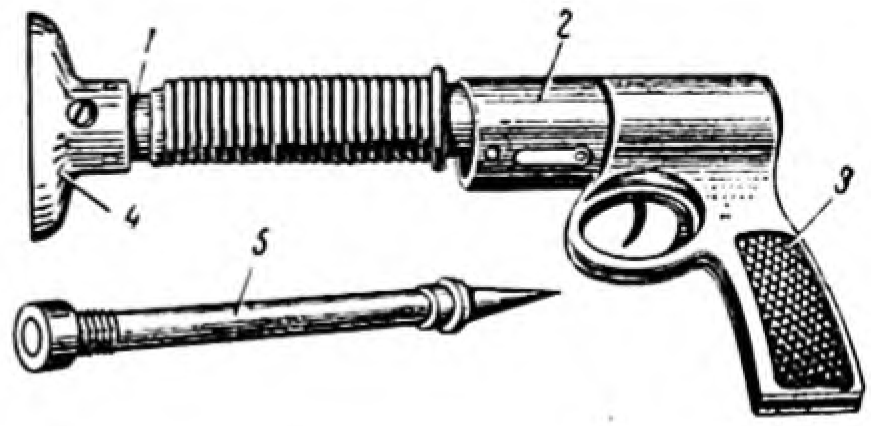


Fig. 67. Powder-actuated stud-driving gun:

1—barrel, 2—body containing the firing pin and trigger mechanism, 3—pistol handle, 4—interchangeable shield ring (for protection against flying particles), 5—fixing stud.

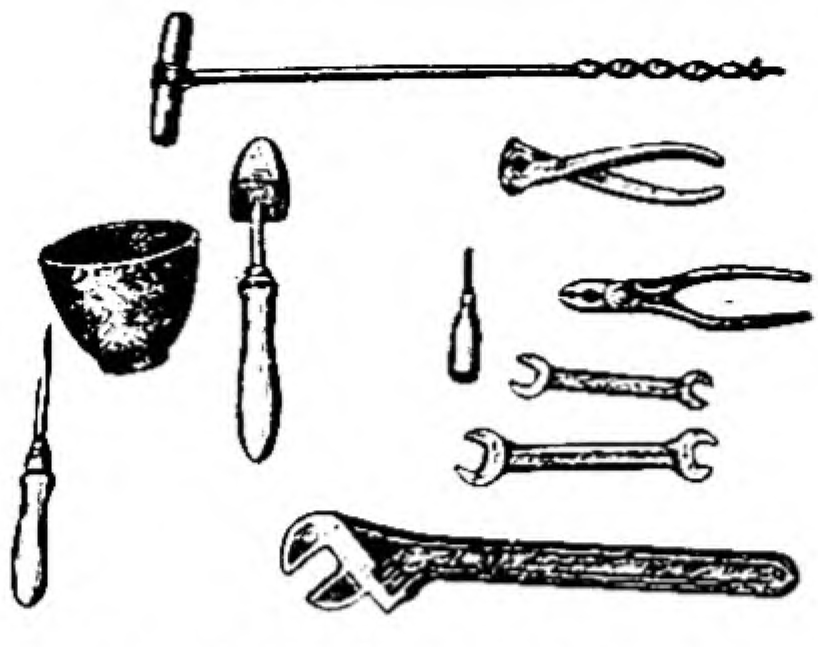


Fig. 68. Tools for doing preparatory work.

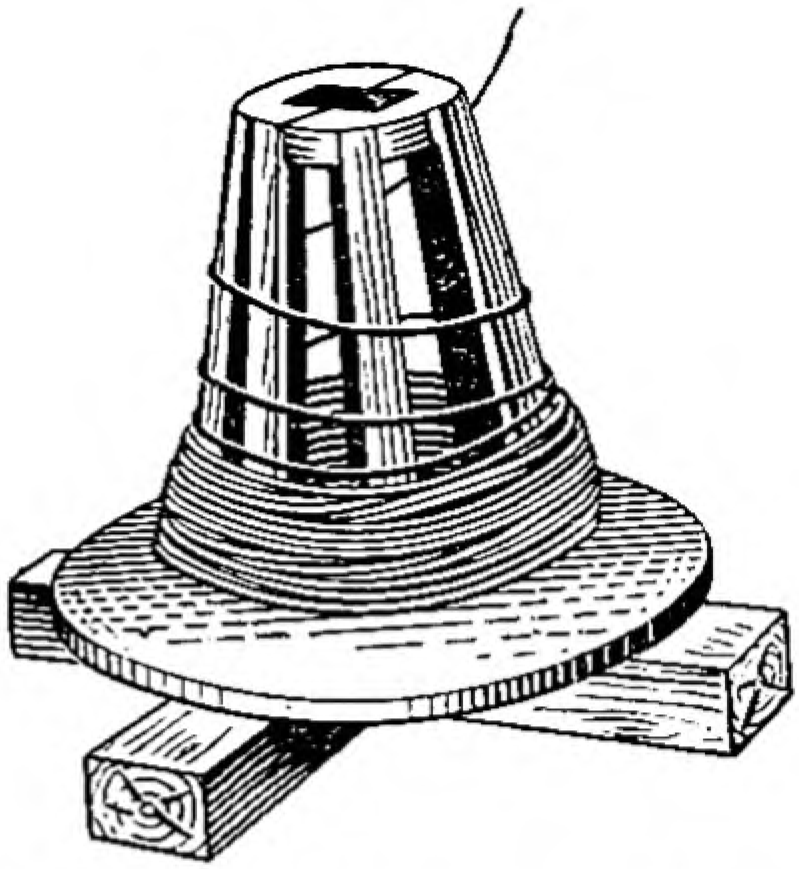


Fig. 69. Wire unreeling stand.

Tools and Appliances for Installing Wires

Wire unreeling stand. A pivoted conical wooden drum for unreeling coils of wire which is secured on a round wooden platform together with which it can revolve on the vertical shaft secured in a base (Fig. 69).

Block and tackle and wire grip. A set of block and tackle and a wire grip serves for engaging a wire and tensioning it (Fig. 70).

The parts and the way a wire grip works are as follows: the wire to be gripped is placed between two parallel jaws *3* and *4*, jaw *4* being rigidly secured to body *2*. Jaw *3* can shift radially along slot *7* and is also hinge-pinned at point *6* to lever *8*. The latter, in a like manner, is hinge-pinned to fixed jaw *4* at point *5* and to lever *11* at point *9*. Lever *11* is pivoted on ring *12* which slides in slot *1*.

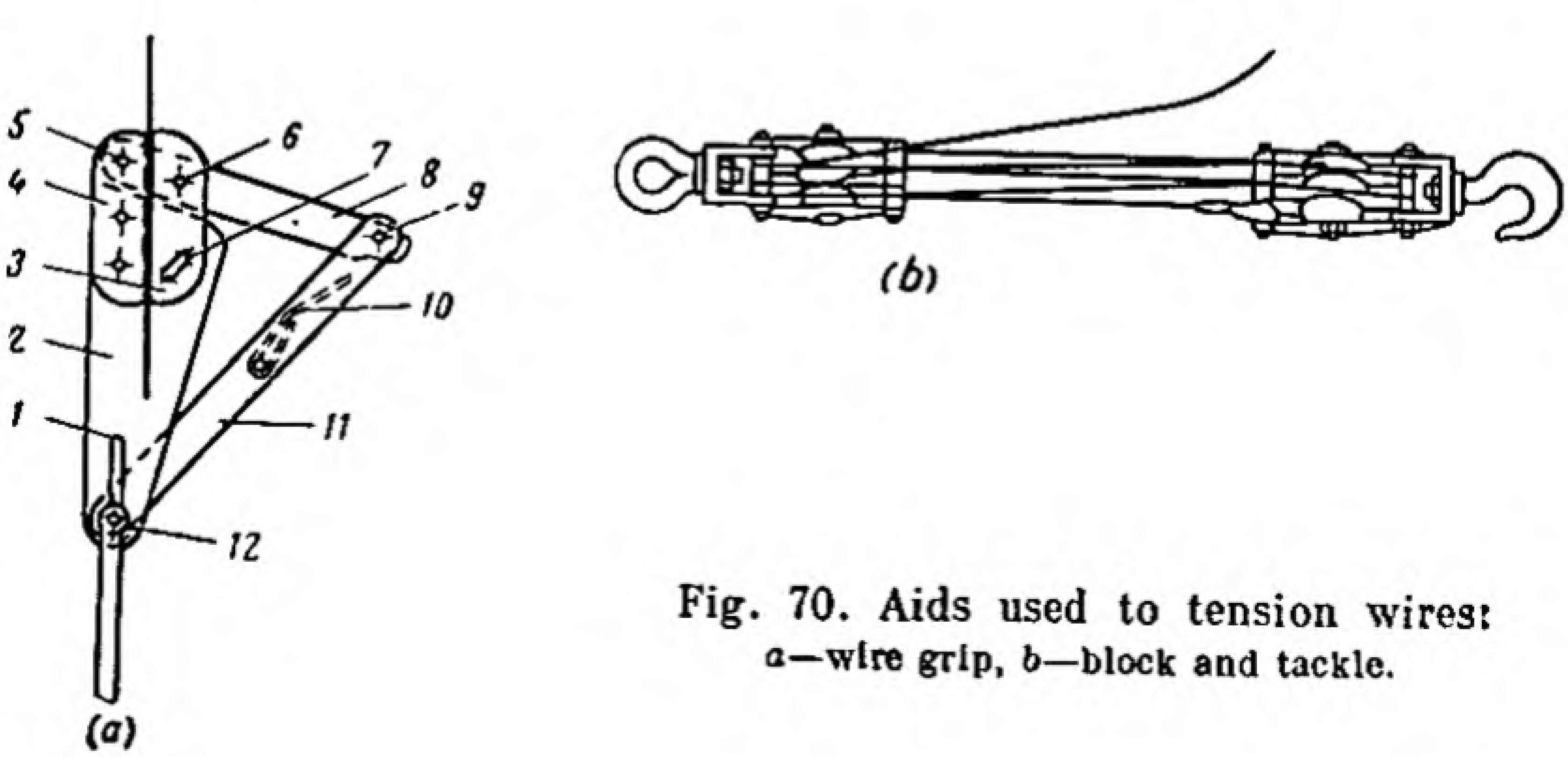


Fig. 70. Aids used to tension wires: *a*—wire grip, *b*—block and tackle.

When tension is applied to ring *12*, lever *11* and its spring travel together with the ring and entrains lever *8*. The moving jaw, as a result of its movement in the direction of the ring, presses the inserted wire firmly against the fixed jaw.

When the tension on ring *12* is slackened, spring *10* separates the jaws of the grip to release the wire.

Transformer and electrode tongs. A unit used to do wire jointing with power obtained from a step-down transformer. The latter can have a primary voltage rating of 127 to 220 volts and a secondary voltage of 12 to 36 volts.

For jointing, the wire ends are clamped with the tongs between its electrodes to attain a welding temperature with the current allowed to pass through the wires from the leads interconnecting the electrodes with the step-down transformer.

Such a transformer unit can be provided with additional tongs incorporating a solder cup for tinning the ends of wire and cord conductors (Fig. 71).

Such tongs consist of two lever arms hinged to each other. At its end one of the lever arms is fitted with a red copper solder cup *1* having a solder-holding capacity of about 20 cu cm; at the end of the other arm a carbon electrode *2* is fitted. The leads from the step-down transformer terminals are passed through the hollow internal part of tong arms *3*.

For safety in use, porcelain insulator sleeves are slipped over the lever-handles. To maintain the tongs in a separated condition a spring is fitted between the tong arms. When the electrode is brought into contact with the solder cup, the flow of resulting current causes the solder in the cup to melt.

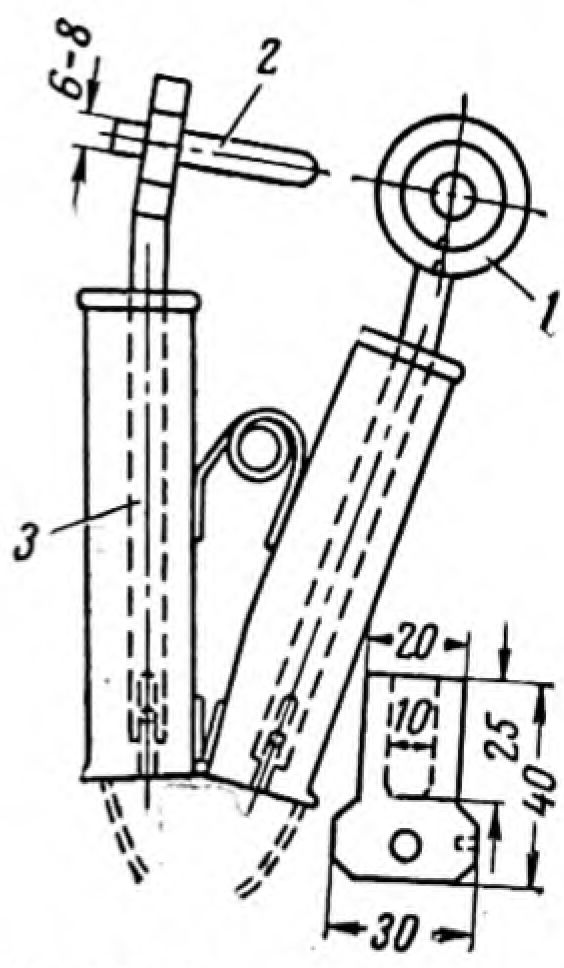


Fig. 71. Conductor tinning tongs.

Compression jointing tongs. Such tongs are used to splice conductors and also terminate them. Conductors up to 10 sq mm in size are jointed and terminated with small model tongs; for conductors of 16 to 50 sq mm large model tongs are used. Conductors larger than 50 sq mm are jointed and terminated with a hydraulic press unit (Fig. 72).

Bending tongs. Seam-jointed, steel-jacketed wires are bent with bending tongs. The knife part of these tongs (Fig. 73*a*) serves to indent the thin sheet-steel jacket at one side of such wire and thus bends the wire to any given radius.

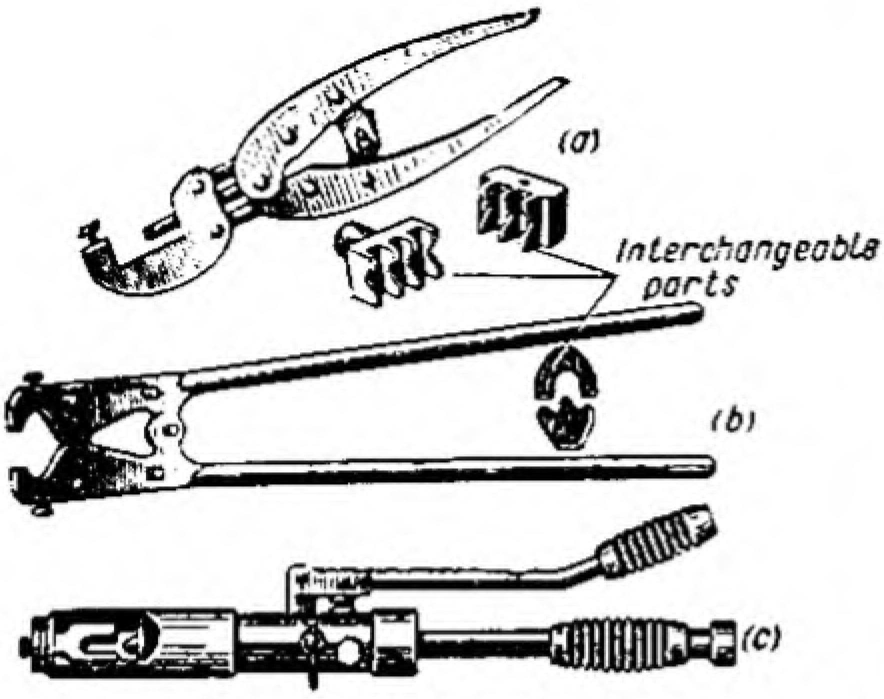


Fig. 72. Tools used for jointing and terminating conductors by compression method:

a—small model tongs, b—large model tongs, c—hydraulic press tool.

Roller type wire straightener. To straighten sheet-steel jacketed wire, two types of roller straighteners find use: bench straighteners, permanently secured for use to a work bench, and hand straighteners (see Fig. 73*b* and *c*).

Soldering torches. Two types of soldering torches, kerosene and petrol, are used for local

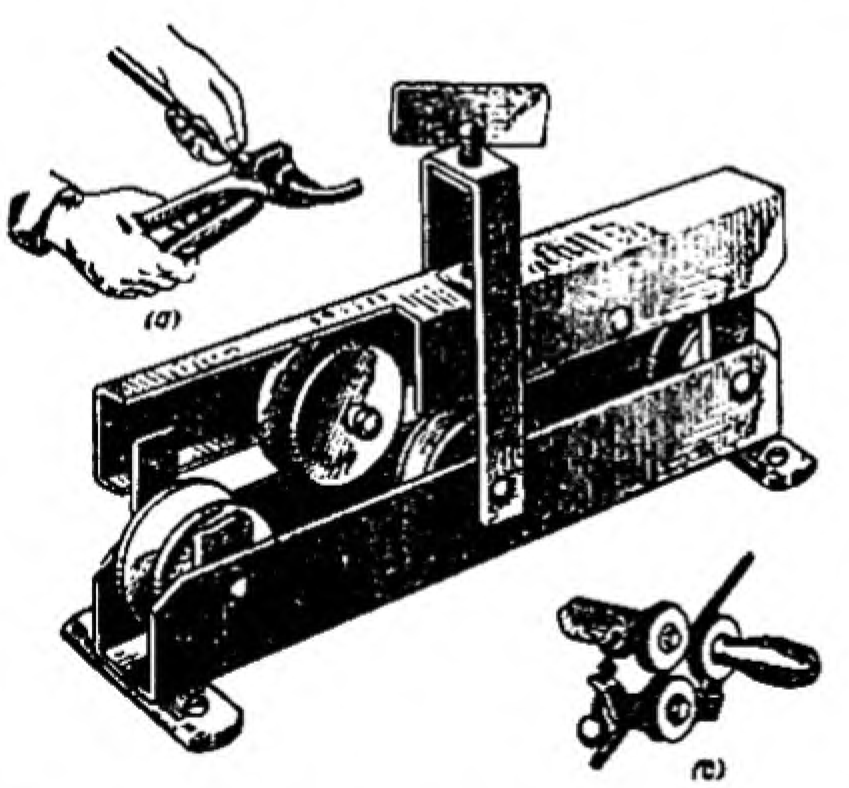


Fig. 73. Tools used to straighten and bend grade ТПРФ (TPRF) lock-jointed, steel-sheath wire:

a—wire-bending tongs, b—bench-mounted roller straightener, c—hand-type roller straightener.

heating of conductors in soldering connector lugs on conductors and in making splices and tap-off joints.

Other tools required to perform wiring work are tools such as electrician's knives, hacksaws, levels, etc.*

Special Metalworking Tools

A large proportion of the operations performed in the course of electrical construction and wiring involves the working of metals from which support arrangements and fixing parts are

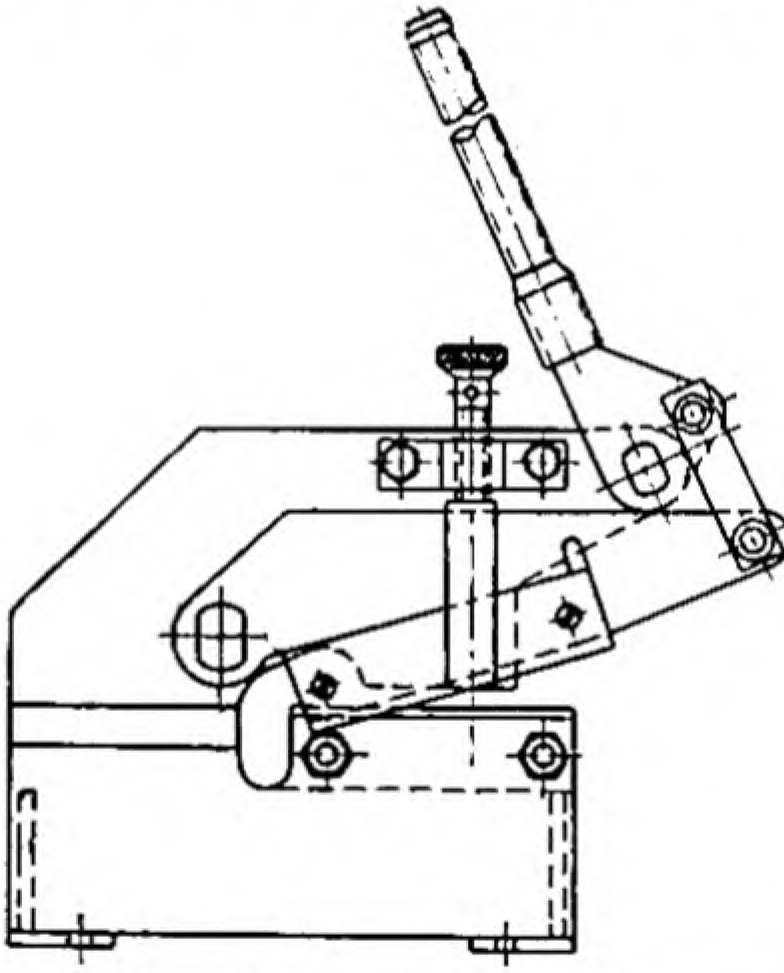


Fig. 74. Model PH hand-operated shear.

made. Of the simplest metalworking tools are a model PH (RN) hand-operated shear (Fig. 74) used to shear strip and sheet

* When electrical installation work is carried out, use is made of a number of different installer's tools and appliances. Their use will be pointed out when the various particular installation operations are discussed.

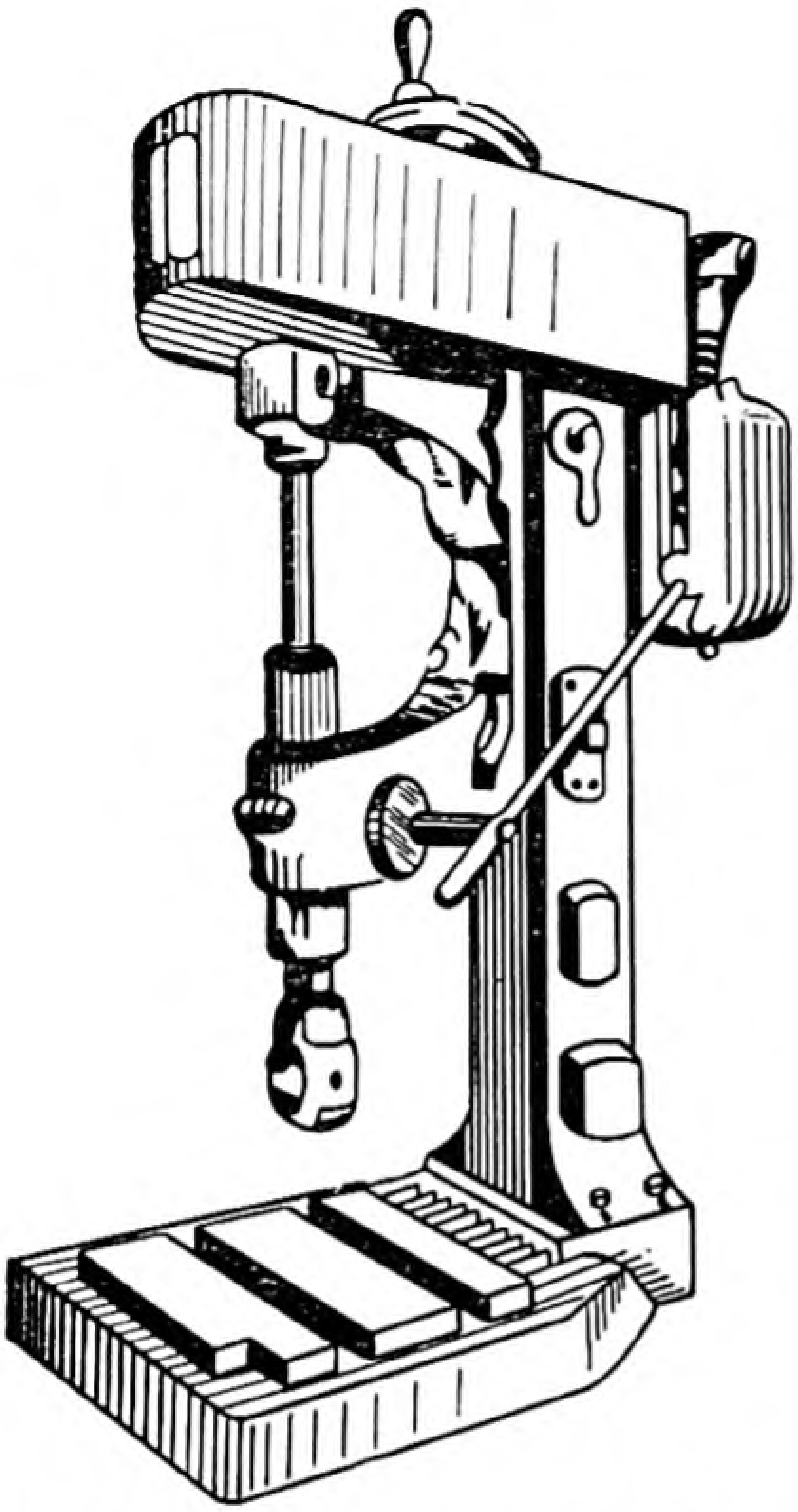


Fig. 75. Bench-type drilling machine.

steel, and a bench-type drilling machine (Fig. 75) used to drill, ream and countersink holes up to 14-mm in diameter.

3. Knob Insulator Wiring

Wiring with Rubber-Covered Grade ПР (PR)

Knob insulator wiring with grade ПР (PR) unprotected rubber-covered single-conductor wires is used for voltages up to 500 volts and is installed in premises with dry and moist atmospheres and also under shelter roofs in outdoor installations. In industrial premises, this kind of wiring is used to install the lighting circuits in the shops, passageways, storerooms and personnel welfare premises. In public buildings and offices such wiring is installed in the toilet rooms, stairwells and kitchens. The general appearance of such wiring is illustrated in Fig. 76.

Laying-out and Marking-off Operations. *Laying out and marking off for installation of lighting units.* If one lighting unit is to be installed in a room, it is placed at the centre of the ceiling where the diagonals from the corners of the room intersect with each other (Fig. 77*a*). The diagonals can be marked off with a cord on the floor and the point of intersection of the diagonals transferred to the ceiling

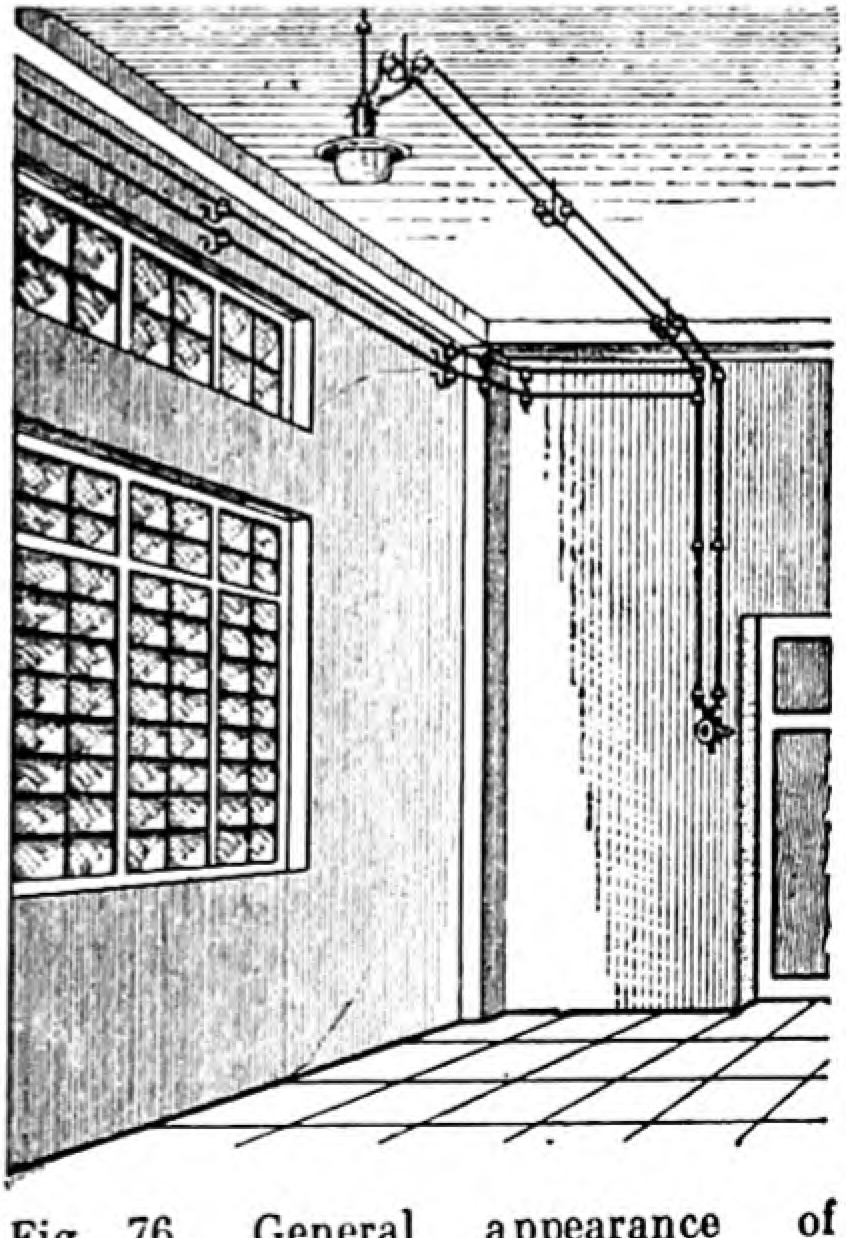


Fig. 76. General appearance of wiring installed with grade ПР (PR) rubber-covered wire on knob insulators.

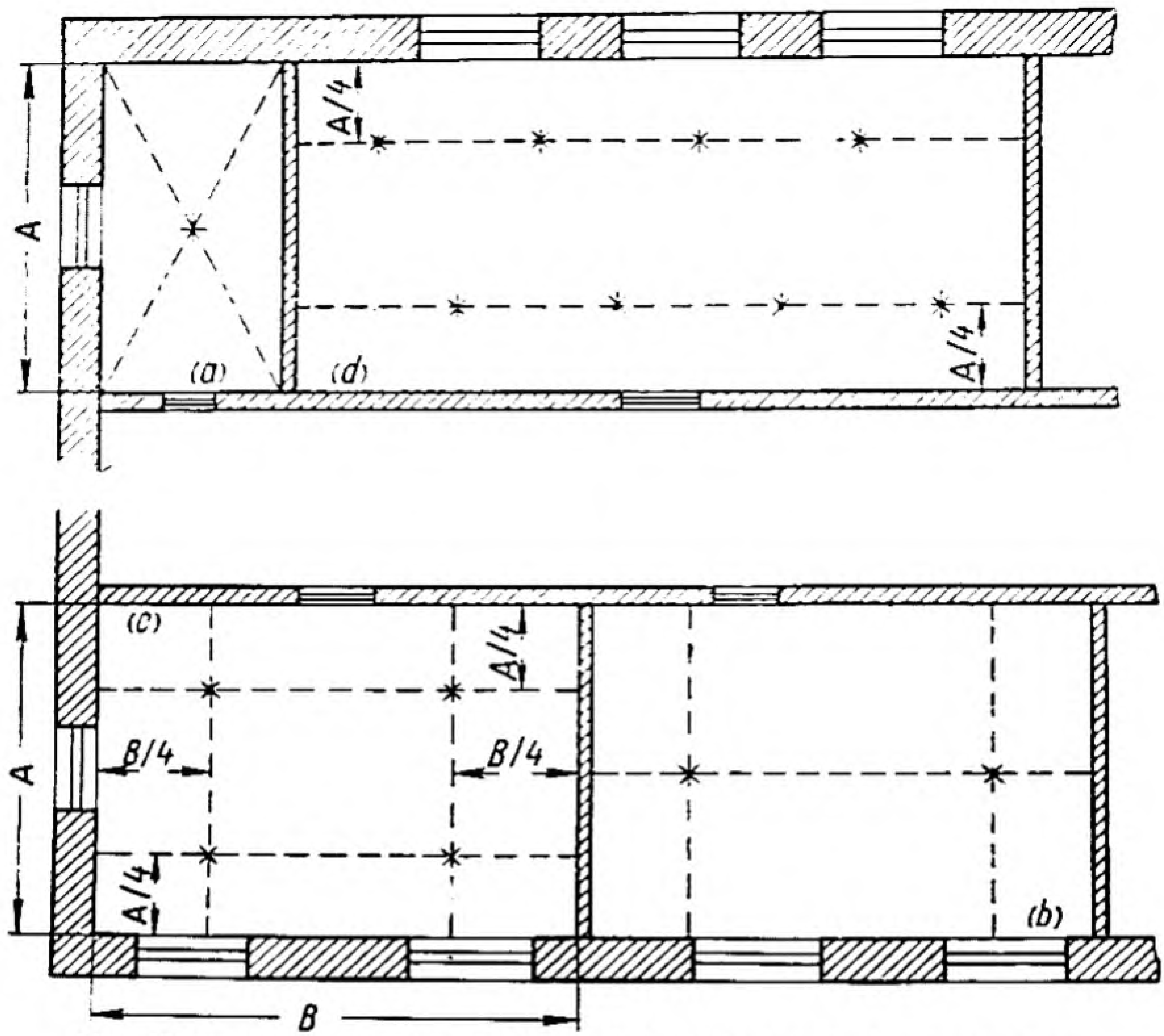


Fig. 77 Laying out and marking off for lighting fitting mounting:
a—for one lighting fitting, *b*—for two lighting fittings, *c*—for four lighting fittings, *d*—for staggered lighting fittings.

by means of a plumb bob and plumb line.

Diagonals are marked off on a ceiling by two men working on straight or step ladders placed in the opposite corners of the room in order to stretch the colour-coated marking-off cord from corner to corner.

To simplify this operation, it is advisable to use a marking-off stick and thus avoid the need for a second straight or step ladder.

When working with a marking-off stick, one of the men holds the free end of the cord, previously unwound to a sufficient length, and climbs the ladder placed in one of the corners of the room. The second man, by means of the stick, can now hold the other end of the cord up against the ceiling at the opposite corner. The first man stretches the cord tight and beats off the diagonal on the ceiling. The second diagonal between the other two opposite corners is marked off in the same manner.

To install two lighting units in one room (Fig. 77*b*), the centre

line is marked off on the ceiling and the points of installation are then measured off on the centre line.

Lighting fitting places of installation can be laid out in a simpler manner by using marking-off dividers.

The most common spacing arrangement used for installing four lighting units in a room is shown in Fig. 77*c*.

In industrial premises it is rather common practice to stagger the lighting units as shown in Fig. 77*d*.

Care must be taken to strictly observe the necessary distances between lighting units, and between the lighting units and walls; these distances are, as a rule, given on the floor plans, or may be scaled from the drawings.

Marking off for installation of switches and plug sockets. Switches must be installed at 1,600 to 1,700 mm from finished floor level, plug sockets—from 800 to 900 mm from finished floor level.

The centres of the switches and plug sockets are marked off by using marking-off rods on which lines have been made at the corresponding heights of 1,600 to 1,700 mm and 800 to 900 mm.

Marking off for installation of fuseboards. Lighting circuit fuseboards are usually mounted on anchor studs. In such cases laying out and marking off consists in locating the axes of symmetry at the place of fuseboard installation after measuring off the proper height from finished floor level. After this the centres of the holes for cementing-in of the anchor studs are marked off. To speed up such work, the use of a marking-off template is recommended.

Marking off lines of wiring. Grade ПР (PR) rubber-covered wire can be installed on separately fixed knob insulators, on knob insulators secured to screw-fixed or cemented-in anchor plates, and on knob insulators secured to strip-steel stirrups.

The lines along which the individually fixed knob insulators, screw-fixed anchor plates and cemented-in anchor plates are to be installed must be marked off according to the specified spacings to be observed between centres of the knob insulators (Fig. 78*a*, *b* and *c*). Marking off for stirrup-installed circuits is done with two lines at a distance from each other equal to the distance between centres of the stirrup feet (Fig. 78*d*).

For wiring with grade ПР (PR) rubber-covered wire installed on knob insulators, the main spacings to be observed between insulators are given in Table 13.

At places where lines of wire make a 90-degree turn, marking off must be done so that the diagonal distance between the knob insulators is 1.4 times greater than the distance between lines (Fig. 78*e*).

When the wires to be installed are large in number, marking off of the lines can become rather involved. In view of this, the circuit diagram of floor plan should first be thoroughly studied to clearly picture the purpose and direction of each separate wire.

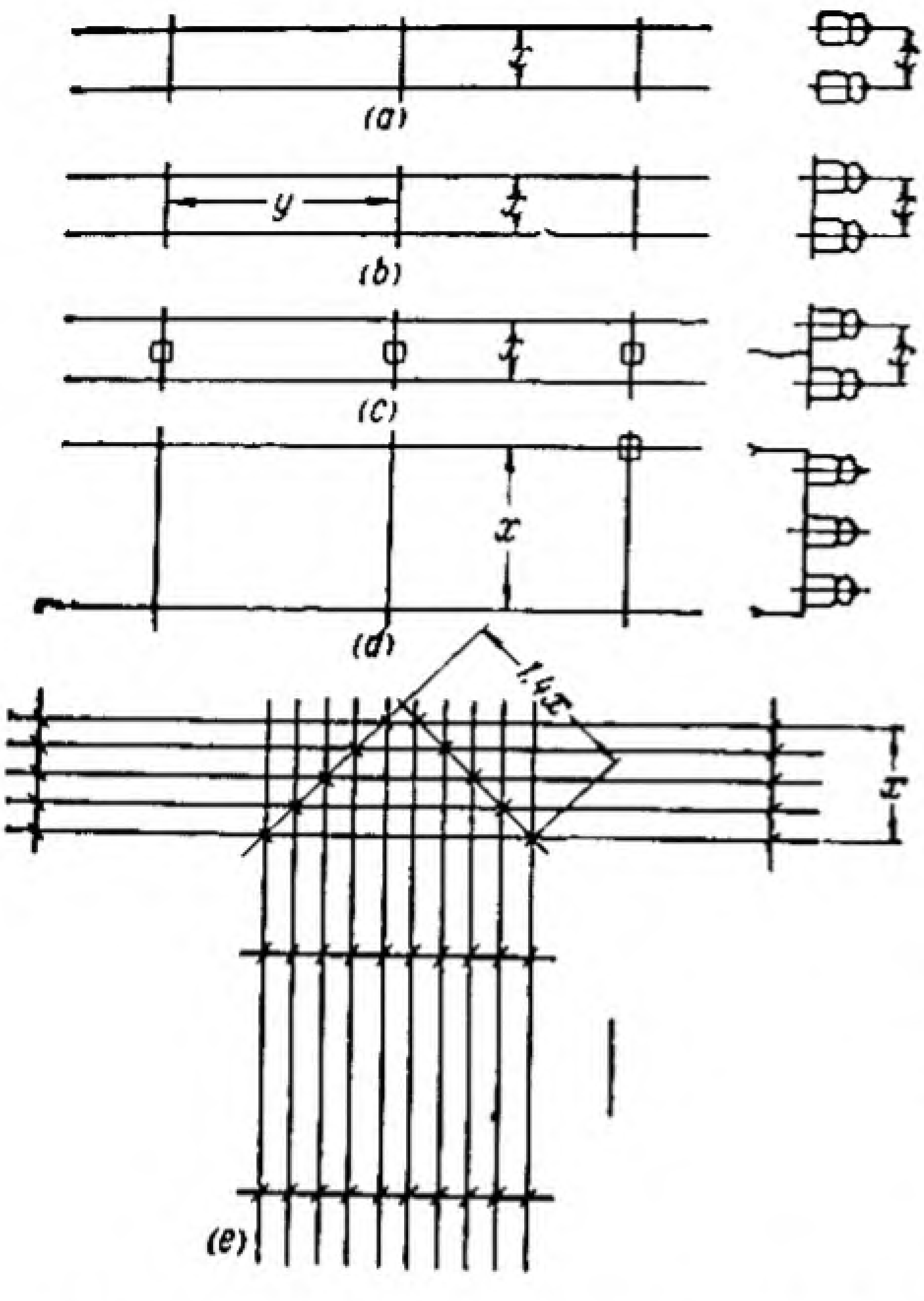


Fig. 78. Laying out and marking off of lines for installing:

a—separately fixed knob insulators; b—knob insulators secured on screw-fixed anchor plates; c—knob insulators secured on cemented-in anchor plates; d—knob insulators secured on stirrup supports; e—knob insulators at a turn in direction of wiring.

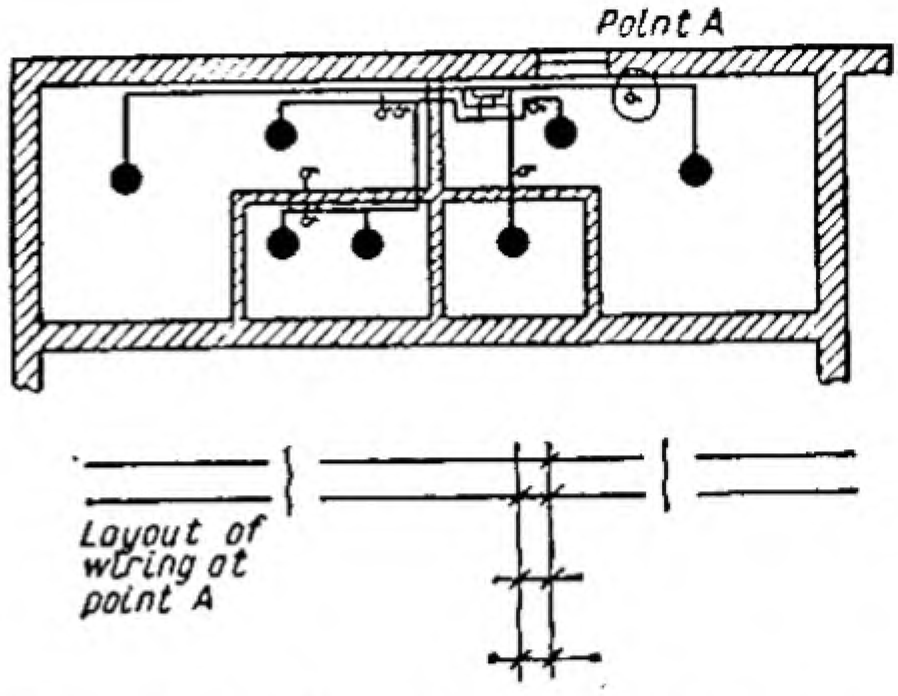


Fig. 79. Interpretation of a floor plan for marking off lines of wiring at a given point.

An example of the interpretation of a floor plan for marking off the lines of wiring for a given point is shown in Fig. 79 (for point A).

Preparatory work. *Mounting of fixing parts.* When grade ПР (PR) rubber-covered wire is installed on knob insulators on wooden unplastered surfaces, each knob insulator is fixed individually. Size РП-2 and РП-6 (RP-2 and RP-6) knob insulators are in such cases secured with round-head wood screws, while size РП-16, РП-35, РП-70 and РП-120 (RP-16, RP-35, RP-70 and RP-120) knob

Table 13

Spacings for Wiring with Grade ПР (PR) Rubber-Covered Wire Installed on Knob Insulators

Centre-to-centre distance between knob insulators	Distance (mm) for wires of following size (in sq mm):				
	1-2.5	4-10	16-25	35-50	70-120
Minimum lateral spacing (dimension x in Fig. 78)	35	50	50	70	100
Maximum span between supports along run of wire (dimension y in Fig. 78)	800	1,000	1,200	1,200	1,200

insulators are secured with lag screws.

Two washers are placed under the head of each lag screw; a pressboard washer (lower) and a steel washer (upper). The pressboard washer cushions the pressure exerted on the knob insulator and the steel washer protects the pressboard washer from being torn when the lag screw is drawn tight. Prior to securing a knob insulator, a preliminary hole for the screw is sunk with an awl or a gimlet. The best tool to use for driving lag screws is a socket wrench.

Wiring installed on plastered wooden surfaces should not be secured on knob insulators which are individually fixed to the surface because the tension applied to the wires when tightening may break the layer of plaster. Knob insulators, for fixing on plastered wooden surfaces, are secured to anchor plates. This increases the area of support in contact with the plastered surface, reduces the pressure on the plaster and thus precludes the possibility of breaking the plaster.

Anchor plates on which size РП-2, РП-6 and РП-16 (RP-2, RP-6 and RP-16) knob insulators are secured are fixed to the support surface with wood screws. Anchor plates with size РП-35, РП-70 and РП-120 (RP-35, RP-70 and RP-120) knob insulators are fixed with lag screws.

Intermediate anchor plates are fixed only through the free holes drilled in the plates; dead-end and corner-turn plates are fixed through the holes in the knob insulators.

Knob insulators, when installed on brickwork and on concrete surfaces with rubber-covered wire up to 2.5 sq mm in size and not over three in number, are fixed with screws set in wire-spiral anchors made from galvanised binding wire 0.5 to 0.8 mm in diameter wrapped round the threaded part of the fixing screw. Preparation of wire-spiral anchors is illustrated in Fig. 80*a*.

The length of the galvanised binding wire needed for making one wire-spiral anchor ranges from 300 to 350 mm.

For cementing the wire spirals in place, holes of 25 to 30 mm diameter and 45 to 50 mm deep are driven in the surfaces with a plain or cape chisel or are drilled with an electric hand drill.

Before a screw with its wire-spiral anchor can be cemented in, the hole made in the surface must first be cleaned of brick or concrete dust and then filled with the plaster of Paris mortar. Immediately after filling, the screw and its spiral anchor are lightly driven into the filled hole (Fig. 80*b*). The mortar forced out of the hole is tamped back with a trowel. When the mortar begins to set, the remainder around the screw is thoroughly cleaned flush with the surface. The screw is now backed out by one and one-half to two turns to free it. If the knob insulators are to be secured at some later period and not immediately, the screw should be fully backed out for coating with a

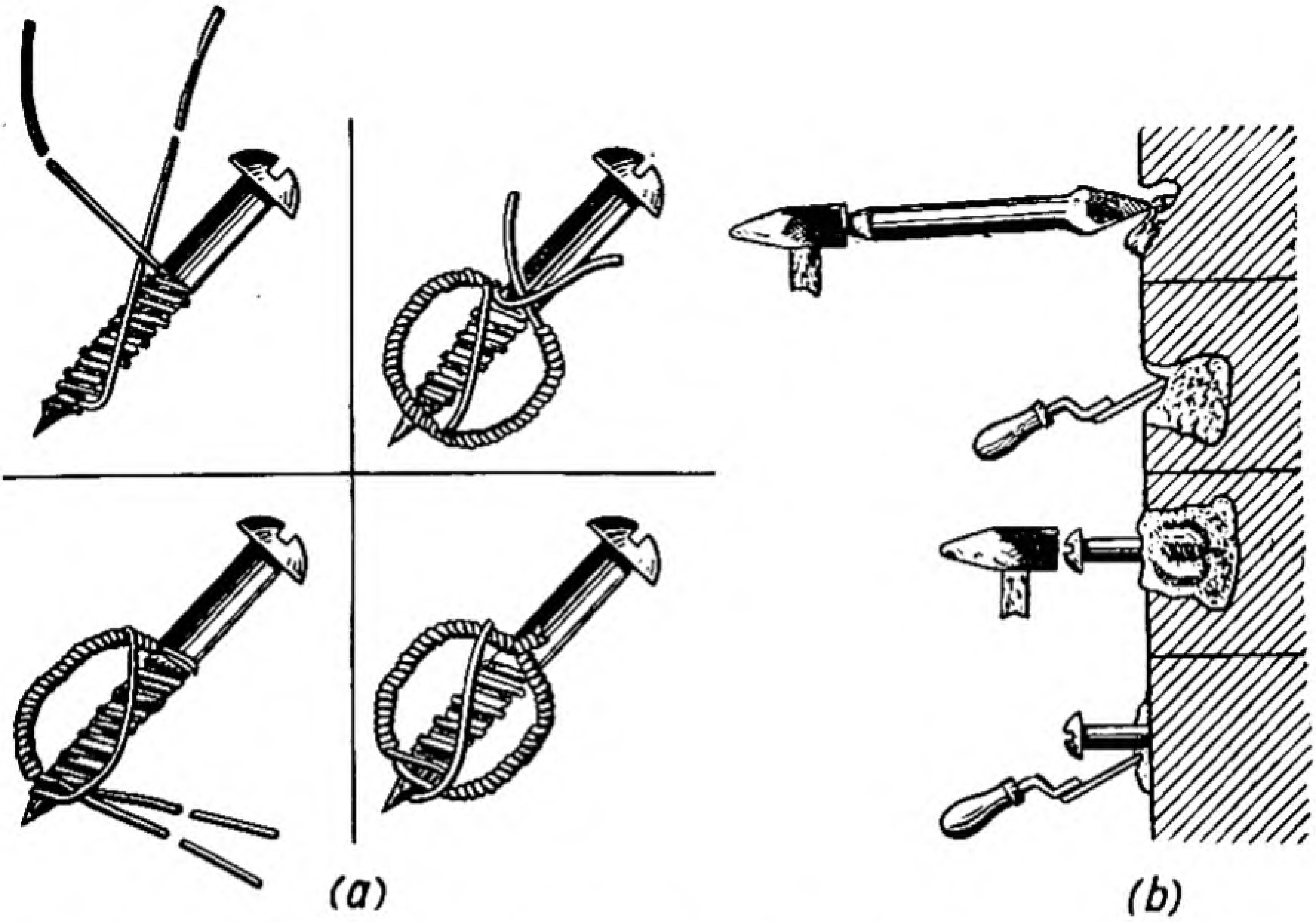


Fig. 80. Sequence of preparing and cementing-in of wire-spiral anchors: a—preparation, b—cementing-in.

thin film of machine oil or petroleum jelly and then screwed back in.

When the size of the wires to be installed exceeds 2.5 sq mm, the knob insulators are mounted with the aid of cemented-in anchor plates.

The hole for securing this type of anchor plate must have a diameter of 25 to 30 mm and a depth of 50 mm and must be made with a chisel or drilled with an electric hand drill. When ready, the hole is cleaned of dust, filled with plaster of Paris or cement mortar, and the embedded part of the anchor plate is lightly driven in with a hammer until the anchor plate proper is flush with the wall or ceiling surface (Fig. 81*a*).

When wires to be installed exceed 16 sq mm in size, the knob insulators are secured to anchor stirrups made from strip steel. Stirrups are also used when the number of wires to be installed is large (5-6 and more).

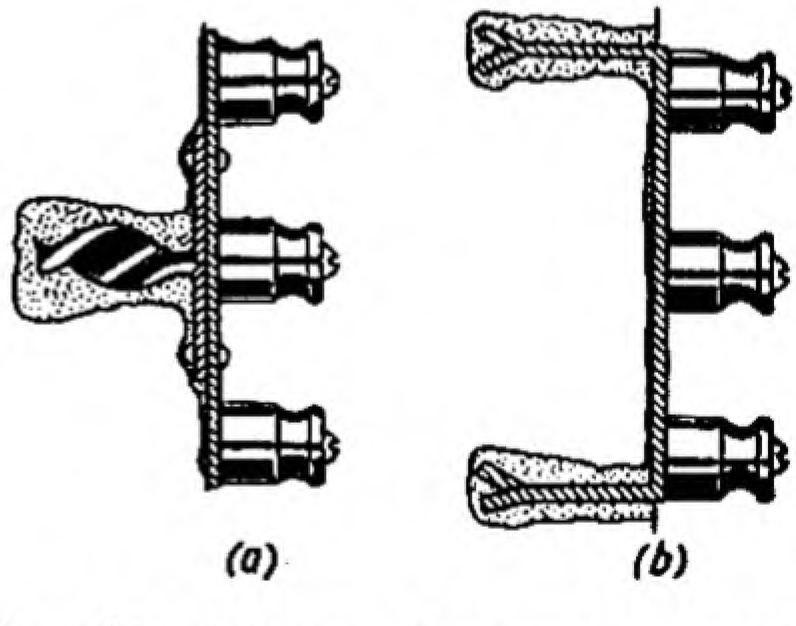


Fig. 81. Fixing of support anchor plates and stirrups:
a—cemented-in anchor plate, b—support stirrup.

For stirrup fixing (Fig. 81*b*), square holes, 75 to 100 mm deep, with the side of the square equal to twice stirrup-strip width, are prepared for the stirrups. After the holes are cleaned of dust and wetted with water, they are filled with plaster of Paris mortar, following which the feet of the stirrups are driven in. That part of the mortar which is forced out is tamped in as fully as possible. It is good practice to force small pieces of broken brick into the mortar to increase its stiffness.

When the stirrup is put in, it must be aligned for horizontality and verticality with a straight edge and a spirit level (Fig. 82). When fixing parts are being put in, the dead-end and corner anchor plates must be cemented in first; after them the intermediate screw-fixed or cemented-in anchor plates and stirrups can be installed. By such a sequence of operations the above intermediate parts can be checked additionally for proper layout of the lines by means of a string stretched between the dead-end (or corner-turn) supports.

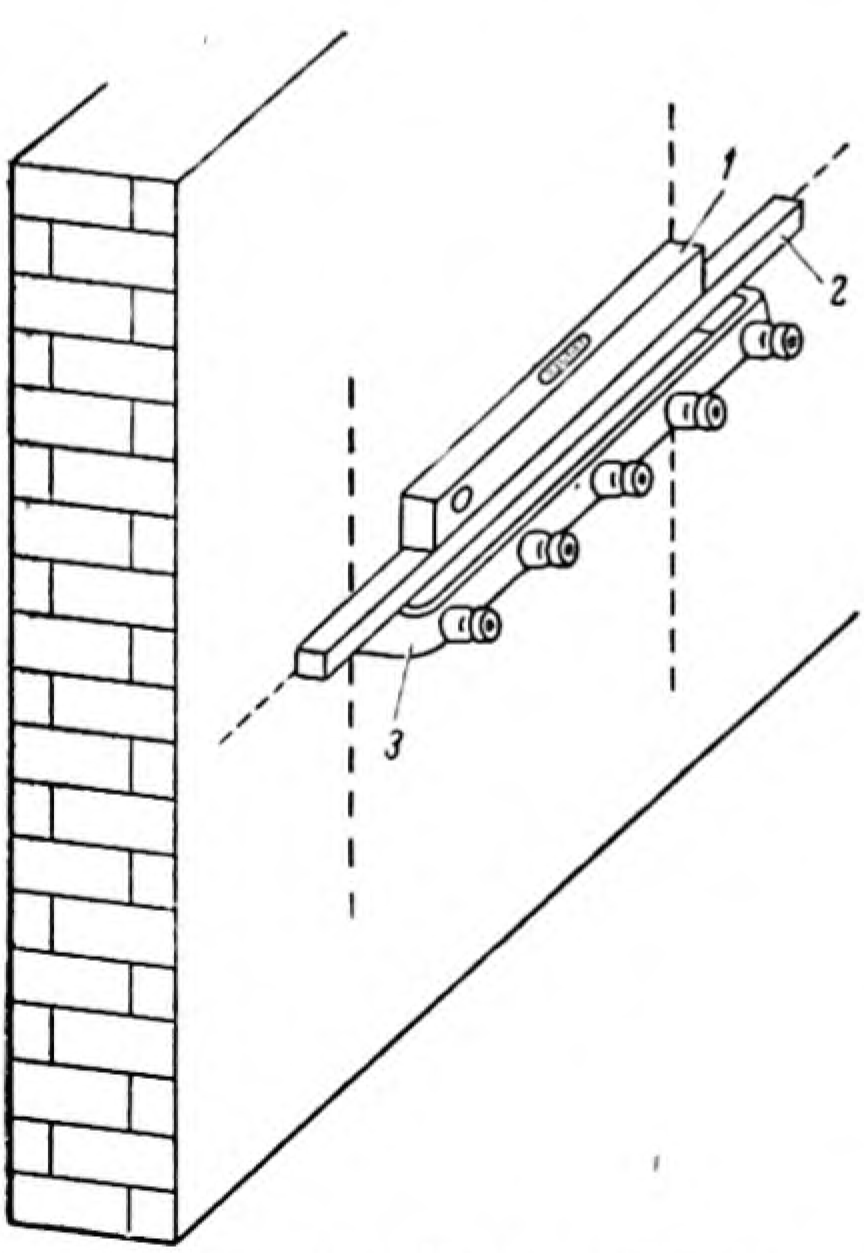


Fig. 82. Levelling a stirrup:
1—spirit level, *2*—straight-edge bar, *3*—stirrup.

Through Hole and Groove Work. To pass wiring from one dry-atmosphere room to another, each wire is run through in a separate length of insulating tubing (Fig. 83*a*).

Where it meets obstacles (Fig. 83*b*) knob wiring is passed under them in grooves with each wire separately protected by a piece of insulating tubing. Semihard rubber tubing is mainly used for this purpose. Porcelain bushings are fitted over the ends of the above lengths of insulating tubing when dry- and moist-atmosphere premises are being wired. In wet premises where the wiring is run buried in grooves,

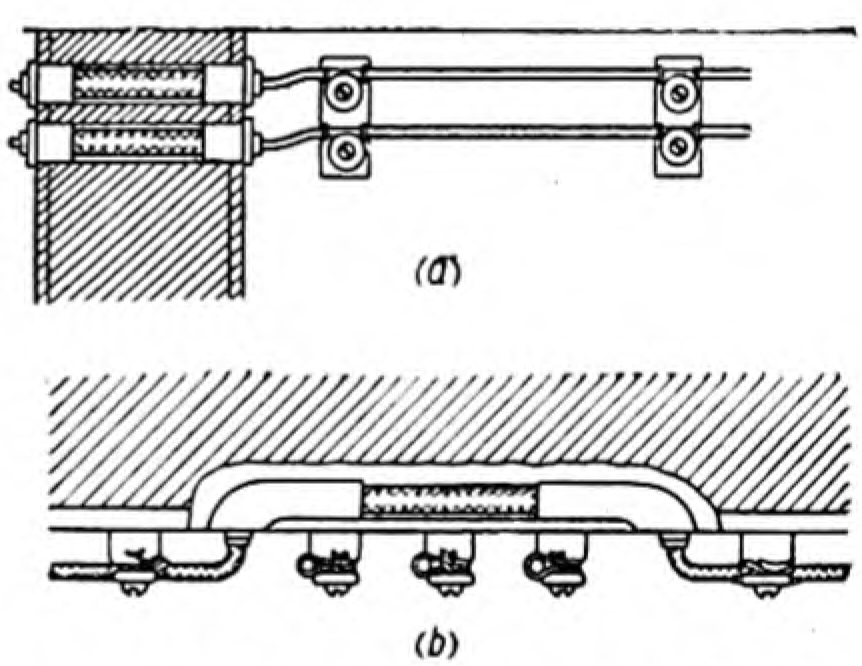


Fig. 83. Arrangements at through holes and obstacles:
a—at through holes, *b*—at intersections with obstacles.

and at service entrances to a building (on outside), the ends of the protective insulating tubing are fitted with bent porcelain tubes which are subsequently sealed with an insulating compound.

To make through holes in wooden partitions, a 3/4″ to 1″ gimlet or an electric hand drill is used. Holes in brickwork and concrete are driven with an air hammer or star drill, or are drilled with an electric drill. Grooves are cut with an air hammer fitted with a special grooving cutter or a chisel.

At through holes the rims of the porcelain bushings must be set flush with the wall surface and the ends of the insulating tubes should be trimmed off at the upper edge of the porcelain bushing or the edge of the bent tube.

At the ends of groove runs the funnel edge of the porcelain bent tube must be set so that it is from 2 to 3 mm above the wall surface.

For multi-wire lines of wiring, in cases such as the above, the porcelain bushings and bent tubes are prepared beforehand in the form of plaster casts for subsequent cementing. To make a bushing plaster cast, the run ends of the bushings are slipped into ready holes in a piece of 3 to 4 mm rubber sheeting, the holes being of the same diameter as the bushing rims and equal in number to the required number of bushings. Any unused holes in the sheet can be sealed off with rubber inserts. The sheet of rubber, with the bushings inserted, can now be placed on a work bench, the bushings surrounded by blocks of wood and the free space between the blocks filled (to about two-thirds of bushing height) with plaster of Paris mortar.

Ten or fifteen minutes later, after the mortar has fully set, the wooden blocks and rubber sheet can be removed and the ready plaster cast cemented in place.

A bent-tube plaster cast is made in a somewhat different way. The bent tubes are secured to each other with thin wire or heavier binding wire and laid out on a plate of glass. Then thin wooden sticks, 2 to 5 mm thick, are laid under the ends of the tubes opposite the throat side. The cast is now made in the same manner as a bushing plaster cast. When the cast hardens, it should be pushed (but not lifted) off the glass plate and then cleaned.

Both bushing and bent-tube plaster casts are cemented in wall recesses with plaster of Paris mortar. After a cast has been cemented in (Fig. 84), the insulating tubes can be put in.

For passage through floor structure wiring must be installed beginning at a height of 2 metres from floor level downward (Fig. 85*a*), either concealed under plaster in insulating tubing, or protected by a conduit pipe (Fig. 85*b*).

Passage holes in floor structures, when they have not been foreseen by the constructors, are drilled with an elec-

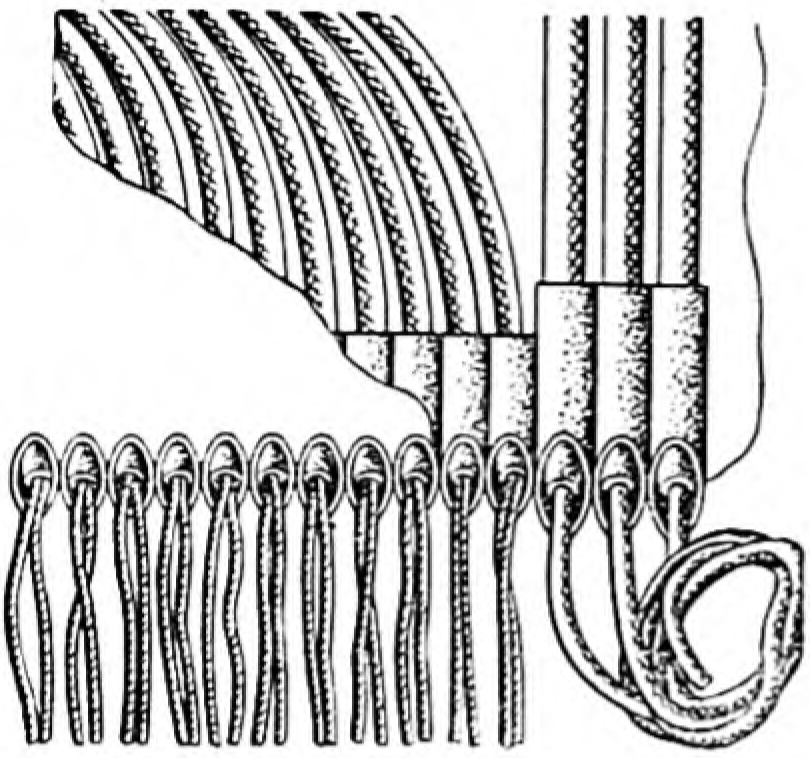


Fig. 84. Group of porcelain bent-tube plaster casts.

tric drill, or driven with an air hammer or star drill.

Wire Installation. Wire is generally shipped to installation sites in coils. Such coils are best unreeled by placing them on a special unreeling stand (see Fig. 69).

If the wire is to be unreeled without using an unreeling stand, care must be taken not to kink

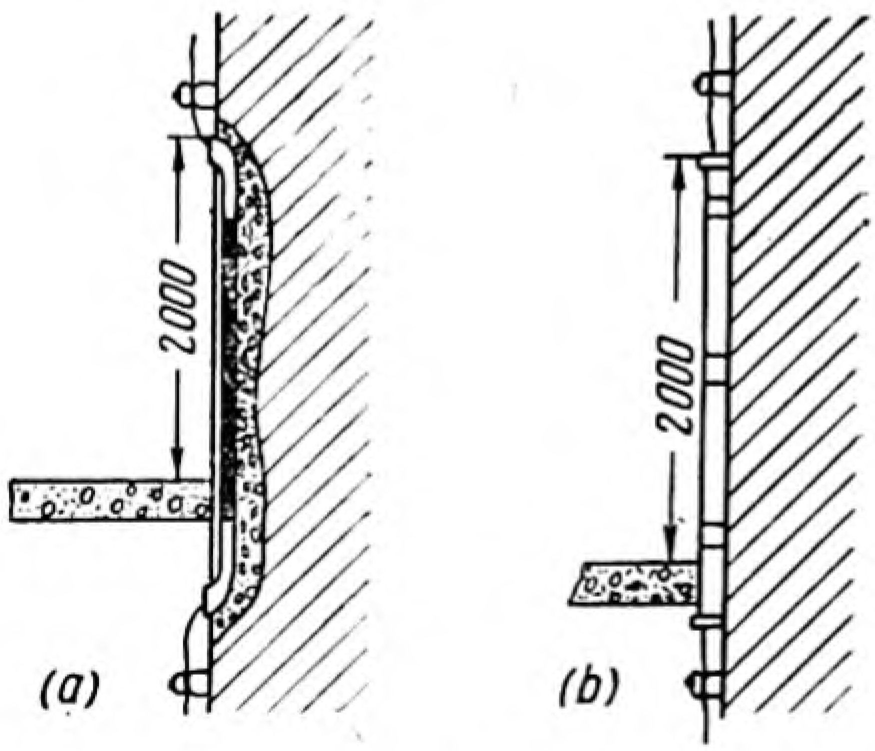


Fig. 85. Passages through between-storey floor structures for wiring with grade ПР (PR) rubber-covered wire installed on knob insulators: *a*—concealed passage in insulating tubing, *b*—concealed in steel conduit pipe.

it (Fig. 86). When kinks are subsequently straightened, it may result in the insulation being damaged and even lead to breakage of the wire conductor.

After unreeling, the wire is measured off according to the measurements of the marked-off lines.

The measured lengths of wire are then tied to the knob insulators with soft galvanised binding wire, the places where the wires are to be tied to the knob insulators being first served with

Fig. 86. Kinks formed in taking wire from a coil.

a wrapping of insulating tape (Fig. 87*b*). For convenience in doing this work, the electrician should first cut the binding wire into ready lengths and make up small convenient rolls of insulating tape (Fig. 87*a*).

As was said above, the wires must first be tied to the far-end knob insulators at one side of a run and then straightened. Wires of small size (up to 16 sq mm) are straightened by pulling the wire through a paraffin-coated rag gripped in one hand. Wires greater than 16 sq mm in size can be partially straightened by pulling them through the rag in the same way and then

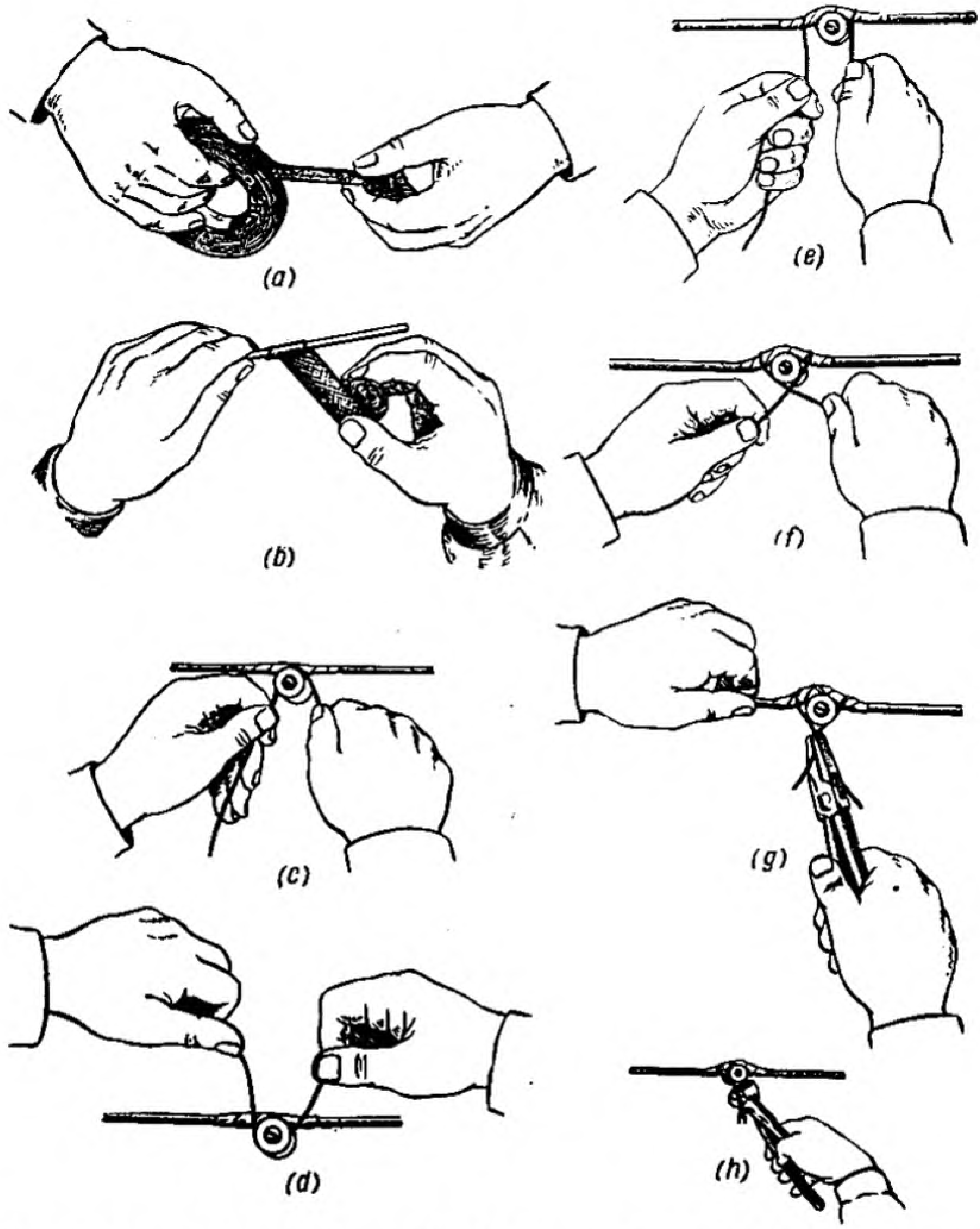


Fig. 87. Securing grade ПР (PR) rubber-covered wire to knob insulators:
a—making up working roll of insulating tape from a full roll of tape, b—applying the wrapping of tape to the wire, c—placing binding wire in knob insulator neck groove, d—making the clamping loop, e—preliminary tightening of clamping loop by hand, f—twisting of the binding wire ends about each other, g—final tightening of the clamping loop with pliers, h—trimming of twisted end of binding wire with end-cutting pliers.

completely straightened by placing the wire on a straight wooden block and striking it with light blows of a wooden hammer. The wire binding process is illustrated in Fig. 87*c*, *d*, *e*, *f*, *g* and *h*.

After a wire has been tied at one side to the far-end knob insulator, it is pulled through the tubing in the grooves and through-hole passages. At the same time the wire is marked off at the places where it is to be jointed and tapped, following which the joints and tap-offs are made.

To joint or make a tap-off joint in single-strand copper wires, their ends must be thoroughly cleaned over a distance l equal to 75 to 100 mm. The joint is made by twisting the ends about each other according to an approved method and then soldering (Fig. 88*a*).

Today, more practised is the compression jointing method

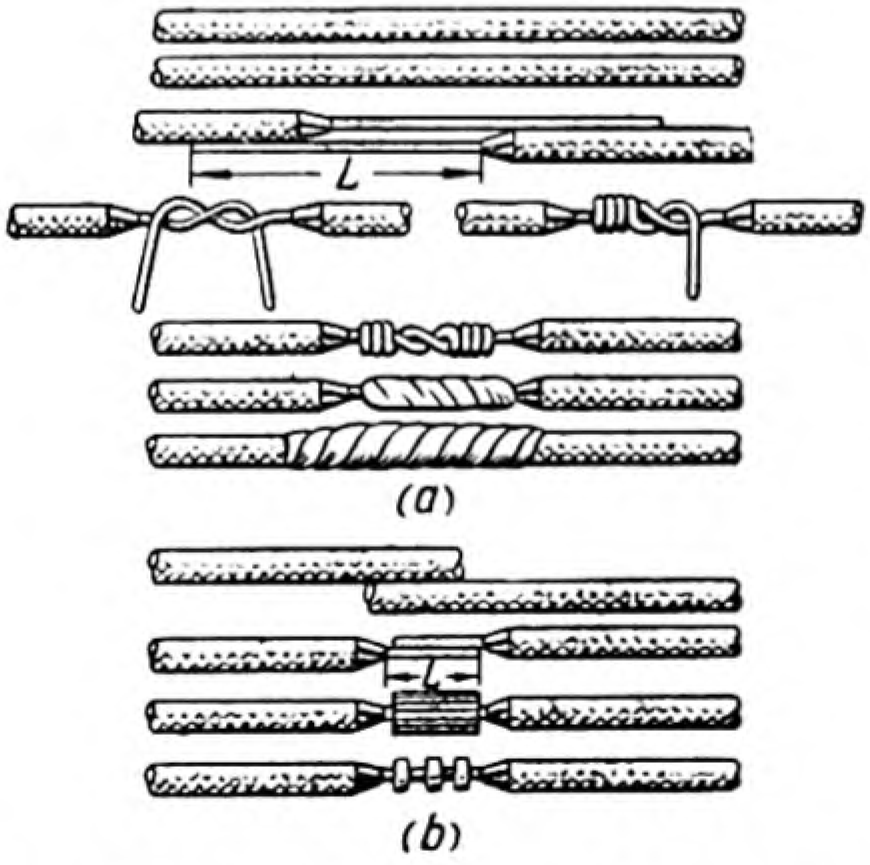


Fig. 88. Splicing of grade ПР (PR) copper, single-strand, rubber-covered wire:

a—ordinary twisted and soldered splice, *b*—splice made by compression method.

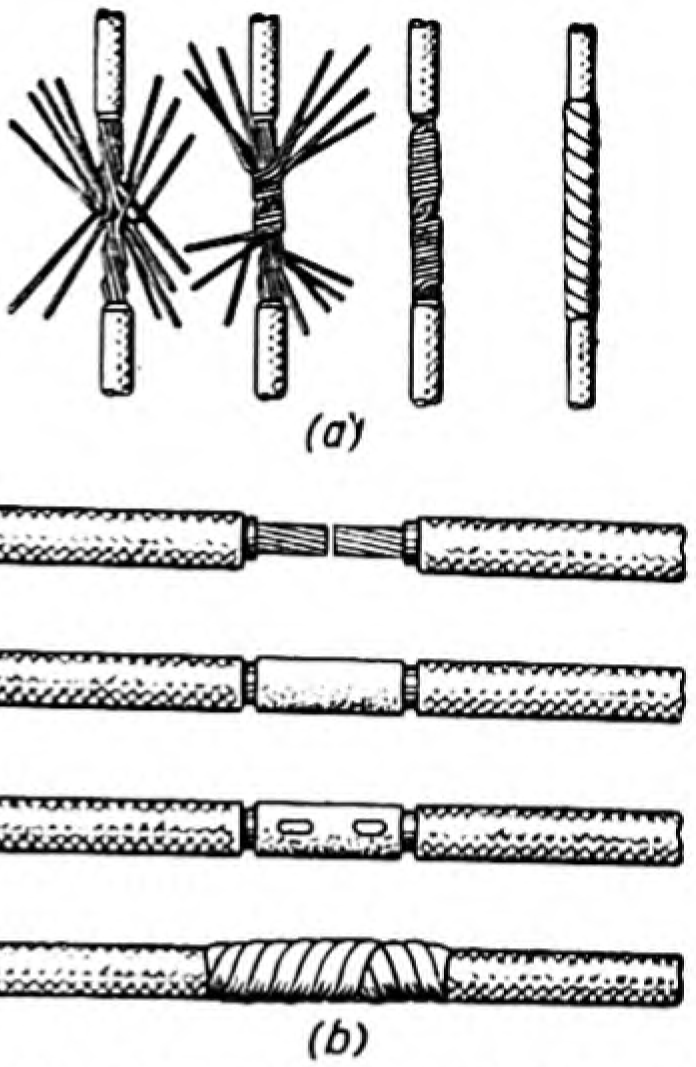


Fig. 89. Splicing of grade ПР (PR) copper, multi-strand, rubber-covered wire:

a—wrap-twisted and soldered splice, *b*—splice made by compression method.

(Fig, 88*b*), for which the ends of the wires must be cleaned to a length of 25 to 30 mm, wrapped with copper foil and then jointed by compression with a model ПК-2 (PK-2) compression-jointing tongs.

Multi-strand copper wires are likewise jointed by a twist splicing method consisting of wrapping the strands about the body of the wire after interlacing them with each other and then soldering the joint or by a compression method of jointing (see Fig. 89*a* and *b*).

Splices and tap-off joints in aluminium wires are made by quite different methods which are explained in detail in special instructions covering these methods.

After the splices and tap-off joints have been completed, each

wire in a given run is tensioned and tied to the knob insulator at the other end of the run. Wires up to 6 sq mm in size do not require any special means for tensioning them. To tension wires 10 sq mm and greater in size, a set consisting of block and tackle and a wire grip is used (see Fig. 70). After the wires have been tensioned and tied to the end knob insulators of a given run, they are tied to their intermediate knob insulators.

Mounting of Lighting Fittings, Switching Devices, Plug Socketsand Fuseboards. Lighting fitting switches hang downward about 150 to 200 mm from the ceiling are directly suspended from ceiling hooks. When they must be hung at greater distances from the ceiling, they are suspended with the aid of tubular (see Fig. 26*e*) or wire rods which also serve for leading the wires into the lighting fitting.

The main wires of a run are directly led down into the furthermost lighting fittings, but at the intermediate lighting fittings it is necessary to tap off special drop leads.

For mounting the lighting switches and plug sockets in knob wiring, wooden rosettes are first secured to the wall surface, flat-head wood screws being used to do the fixing on wooden walls and wire-spiral or plug anchors to fix the rosettes to brick and concrete walls.

The lighting switches and plug sockets can then be secured to the wooden rosettes with wood screws about 25 mm long.

A detailed list of the separate

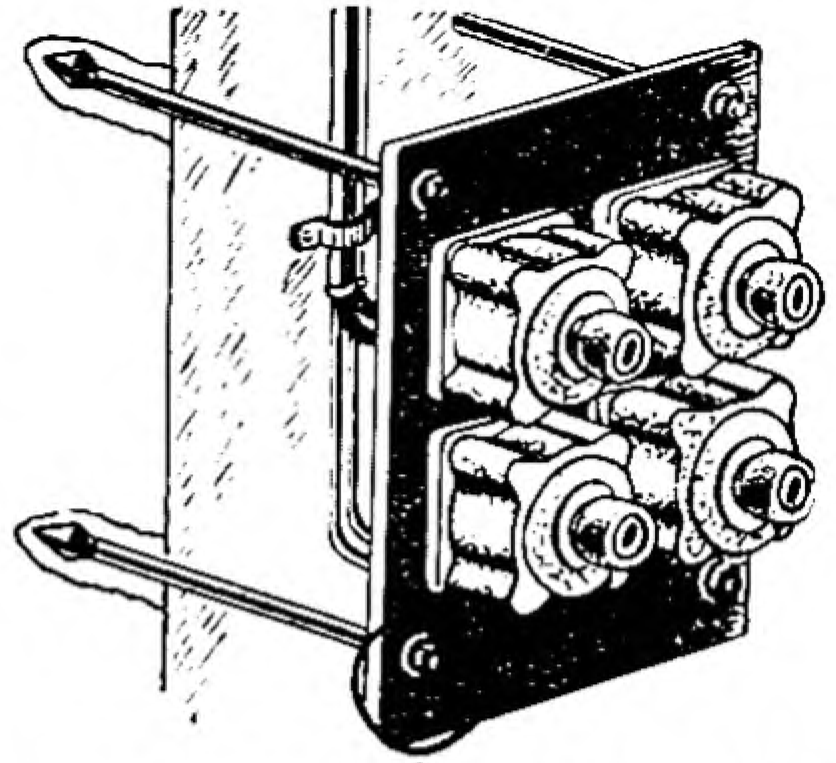


Fig. 90. Grade ПР (PR) rubber-covered wire run down to a fuseboard in steel conduit pipe.

operations to be performed in mounting a lighting switch or plug socket is illustrated in the operation-sequence card given below (Table 14).

Fuseboards of small size (for 3 to 5 branch circuits) are mainly mounted on anchor studs. Large fuseboards (for more than 5 branch circuits) are usually mounted on stirrups of various shape made from strip steel or angle iron.

Since the wiring to be brought in to a fuseboard will take up a space wider than that of the fuseboard, the runs are led behind it concealed (see Sec. 1, Chapter III) under the plaster layer or bunched in a length of pipe conduit (Fig. 90).

Example. It is required that an auxiliary service room in an industrial undertaking be wired with size 1.5 sq mm grade ПР-500 (PR-500) rubber-covered wire installed on knob insulators. A plan of the room with the layout of the circuits is given in Fig.

91*a*. The lighting fittings to be used are of the type called "Universal". The distance from the entrance of the wiring into the room to the fuseboard mounted in the corridor is 3 metres. The scale of the plan is 1 : 100. The fittings are to be hung 0.5 m from the ceiling and the wall surfaces are of plastered wooden construction.

Solution. At first we draw a diagram of the circuits to show all the lines of wiring (Fig. 91*b*). Following this, the lines of wiring can be marked off (Fig. 92) and size РП-2 knob insulators fixed to the ceiling and wall surface with 4 × 50 mm round-head wood screws.

To install the wires we must now measure off the length of wire X_1 from lighting fitting *3* to lighting switch Sw_1, wire

Table 14

Operation-Sequence Card for Mounting a Single-Pole Lighting Switch on a Concrete Wall

Operation	Tools and appliances	Materials	Technical requirements
Marking off point of installation for switch	Plumb bob and line, marking-off rod	Colouring material—chalk, Prussian blue	Mount switch 1,600 to 1,700 mm above finished floor level
Driving of anchoring hole	Type И-38 (I-38) electric drill with cemented-carbide tip drill bit	—	—
Preparation of wire-spiral anchor	Flat-nose pliers and end-cutting pliers	Flat-head 40× ×3 mm wood screw, galvanised binding wire	—
Cementing in wire-spiral anchor	Rubber mixing bowel, trowel, screwdriver	Plaster of Paris	Pay attention to thorough flush clean-off of wall surface at anchor. After mortar hardens, back out screw by 1½ to 2 turns
Fixing wooden rosette	Electrician's awl, screwdriver	Wooden rosette	Pierce hole in rosette and countersink it prior to fixing
Fixing lighting switch	Electrician's awl, lamp-socket size screwdriver	Lighting switch, 25-mm long wood screw	Fix exactly in centre of rosette
Connecting wires to switch terminals and fitting cover	Lamp-socket size screwdriver, electrician's knife, end-cutting pliers	—	—

X_2 from lighting fitting *1* to lighting switch Sw_2, and wire T_1 from lighting fitting *3* up to through-hole passage P.

To the length of wire T_1 we must add 0.75 m for passage through the wall and 3.25 m in order to make connection with the fuseboard (3 m to reach the fuseboard, 0.25 m for tautening and making connection). We measure off wire T_1O from point O up to lighting fitting *1*. In measuring each length of wire, with the exception of wire T_2, we add 0.5 m to each wire for lead-in to the lighting fittings.

We now tie wires T_1 and X_1 near their ends at lighting fitting *3* and stretch the wires up to the position of lighting fitting *4* where we tap-off for lead-down to the latter.

The next operation consists in drawing the wires taut up to the point of pass-over from the ceiling knob insulators and the cornice knob insulators.

Now, after passing through 90 degrees round the corner-turn knob insulators C, wires T_1 and X_1 can be drawn taut up to point O, where wire T_1O, measured off earlier, is tap jointed to wire T_1.

Over the end of wire X_2, measured off beforehand, we now slip a short length of rubber tubing in order to protect it where it must intersect with the other runs of wire. Then, after bringing one end of wire X_2 even with the end of wire T_1O, both the wires are temporarily tied at their ends to the last ceiling knob insulators and the cornice knob insulators.

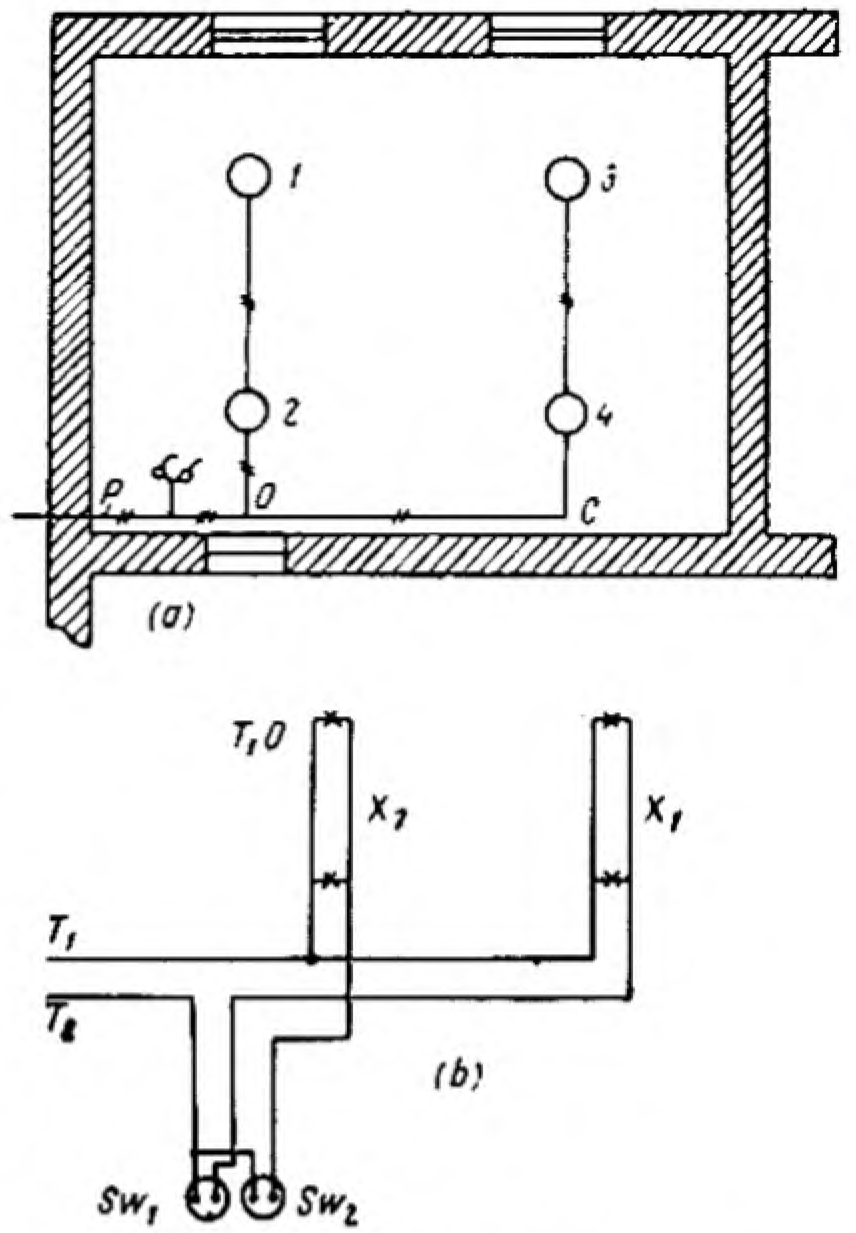


Fig. 91. Floor plan of room giving the layout of the lighting circuit to be installed with grade ПР (PR) wire on knob insulators:

a—floor plan, *b*—full-line diagram of circuit.

Wires T_1, X_1 and X_2 are next stretched up to the knob insulators at which the wires are to be run downward to the lighting switches and from which wires X_1, X_2 and T_2 are dropped to the switches.

Wire T_1 and the free end of wire T_2 are next pulled through the passage in the wall and tied to the end knob insulators at the through hole, this being done after wires T_1 and T_2 have been pulled taut, an operation best performed by exerting a pull on the wires from the external side.

In installing the wires dropped to the switches, wires T_2,

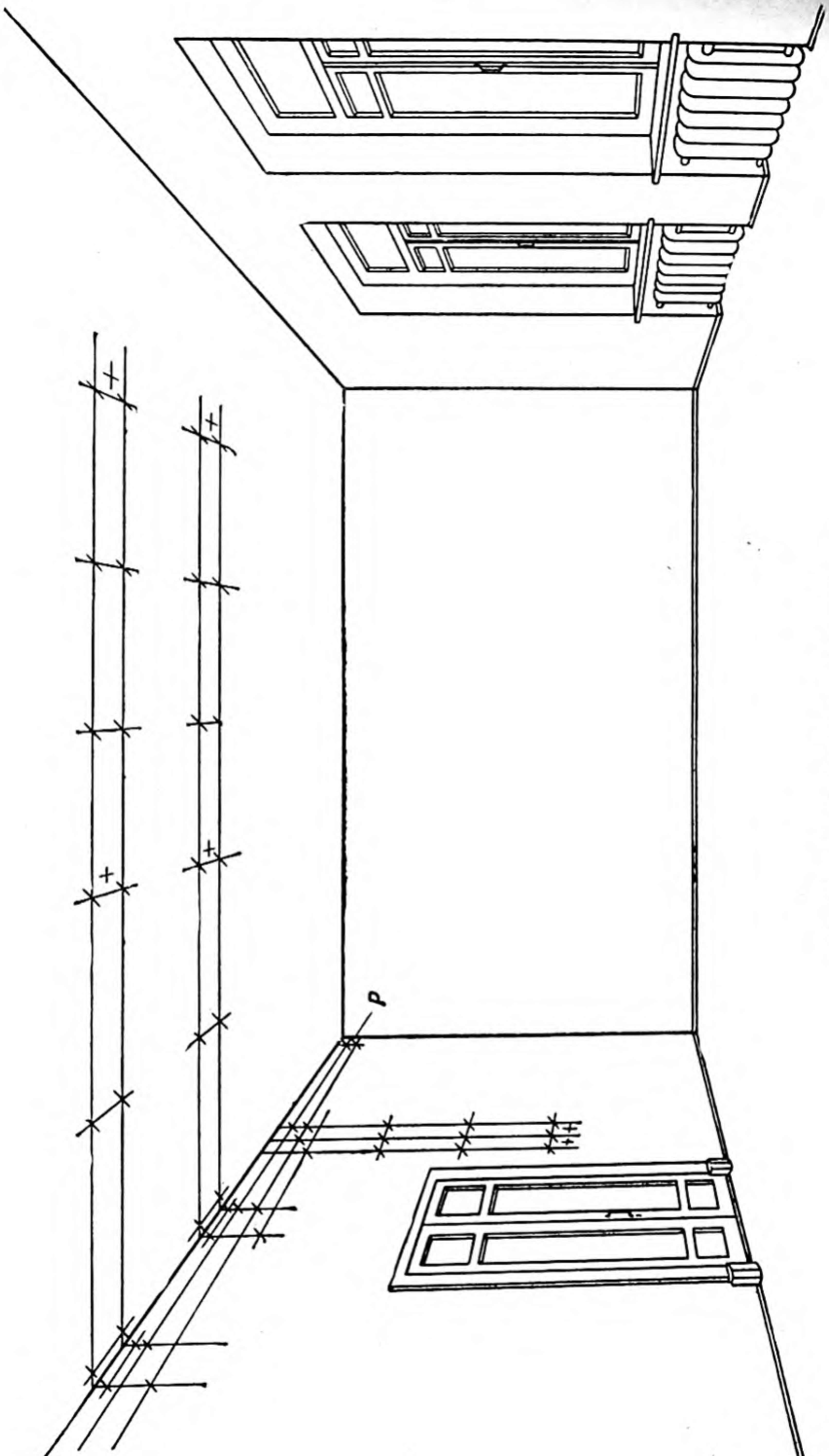


Fig. 92. Marked-off lines for wiring.

X_1 and X_2 are pulled taut and tied to the end knob insulators.

We must now run wires X_2 and T_1O to lighting fittings *1* and *2*, making the necessary tap-off joints with the drop wires for lighting fitting *2*, and then pulling the wires taut for tying them to the end knob insulators at lighting fitting *1*.

The wires can now be finally tied to the knob insulators. We begin by tying the wires at the places where they have been tapped off and then tying them to the knob insulators remaining between them. Straightening of the wires must also be done at this time. After the wiring is in place the lighting fittings and switches are mounted. Wire T_2 is connected to lighting switch Sw_2 by a jumper lead.

Task. Wire a works storeroom with 1.5 sq mm grade ПР-500 (PR-500) rubber-covered wire installed on knob insulators. A plan of the room giving the layout of the circuits is shown in Fig. 93. The scale of the drawing is 1 : 100, the height of the room is 3 m and the lighting fittings

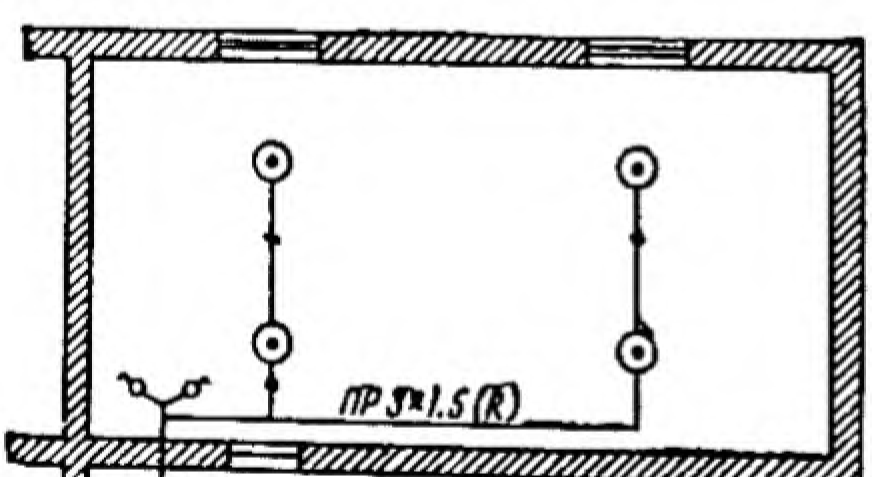


Fig. 93. Floor plan of room and layout of lighting circuit.

to be used are "Lutsetta" one-piece opal glass fittings.*

To answer this problem do the following:

1) draw a full line diagram of the wiring;

2) make sketches showing how the lines of wiring must be marked off;

3) draw up a bill of materials for this job according to the form given below (Table 15);

Table 15

Bill of Materials

Item No.	Name of material	Unit	Quantity

4) Explain in writing what operations must be performed to do this job.

Features of Knob Wiring with Grade ПРД (PRD) Twisted-Pair Wire

Knob wiring with grade ПРД (PRD) twisted-pair wire is used in dry, normal-atmosphere premises for voltages up to 220 volts. This kind of wiring is primarily for lighting circuits in houses, schools, day nurseries, hospitals and premises of like nature.

The general appearance of knob wiring with grade ПРД

* The structural materials of the walls and ceiling in the room are to be stated by the instructor.

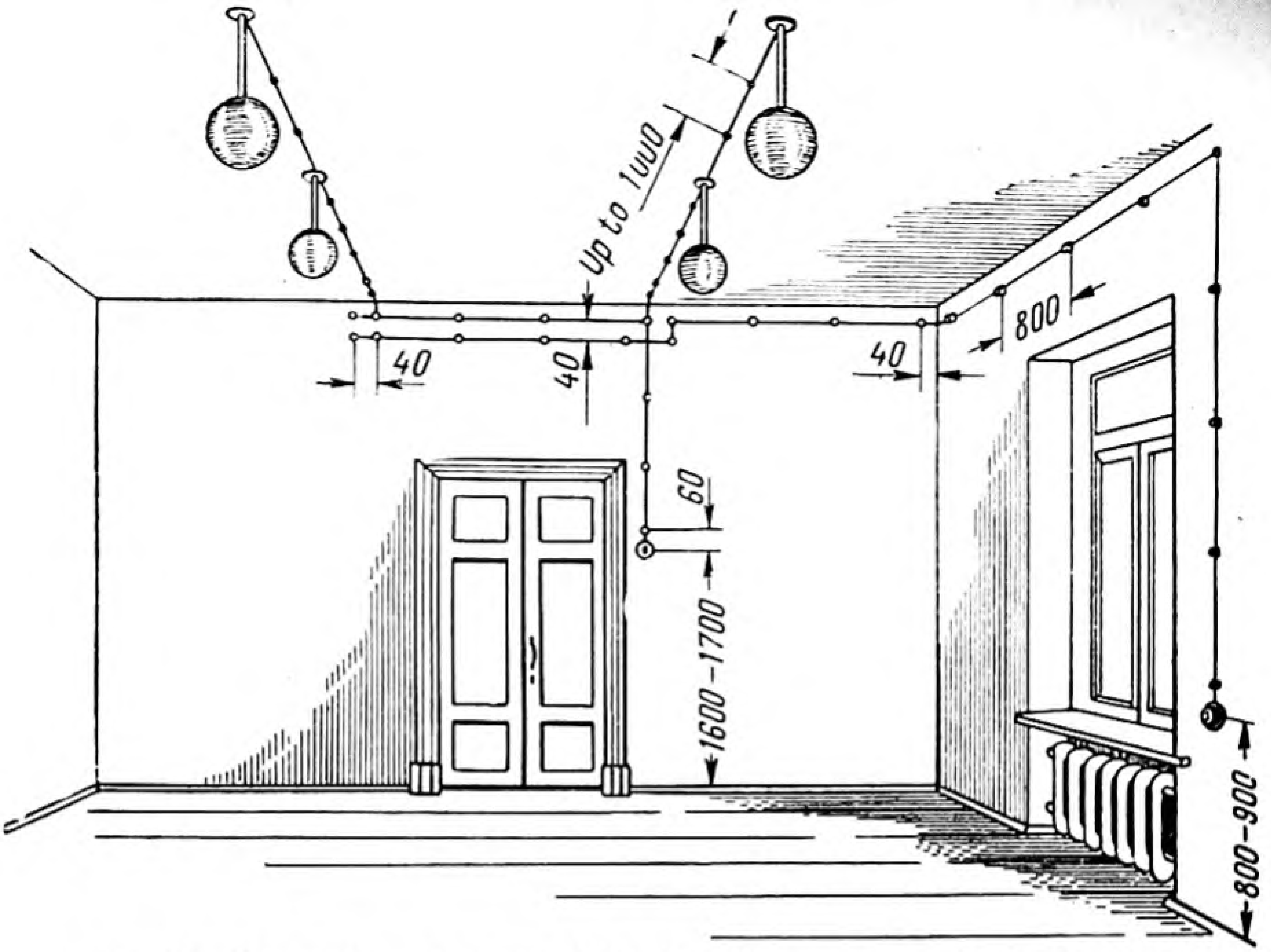


Fig. 94. General appearance of knob wiring with grade ПРД (PRD) twisted-pair wire.

(PRD) wire and the main spacing dimensions (in mm) are shown in Fig. 94.

On wooden-construction surfaces, both unplastered and plastered, the knob insulators for such wiring are fixed with round-head wood screws; on brickwork and concrete surfaces the knob insulators are fixed with the aid of wire-spiral anchors (see Fig. 80) or with dowel plugs (Fig. 95). In place of dowel plugs short pieces of polyvinyl chloride (p. v. c.) tubing may be used. For such fixing, the walls or ceiling are drilled to a definite diameter, a piece of p.v.c. tubing 30 mm long is split along its length, is rolled tight on itself and inserted into the ready hole. The fixing screw, with the knob insulator slipped on, is then screwed into the centre of the

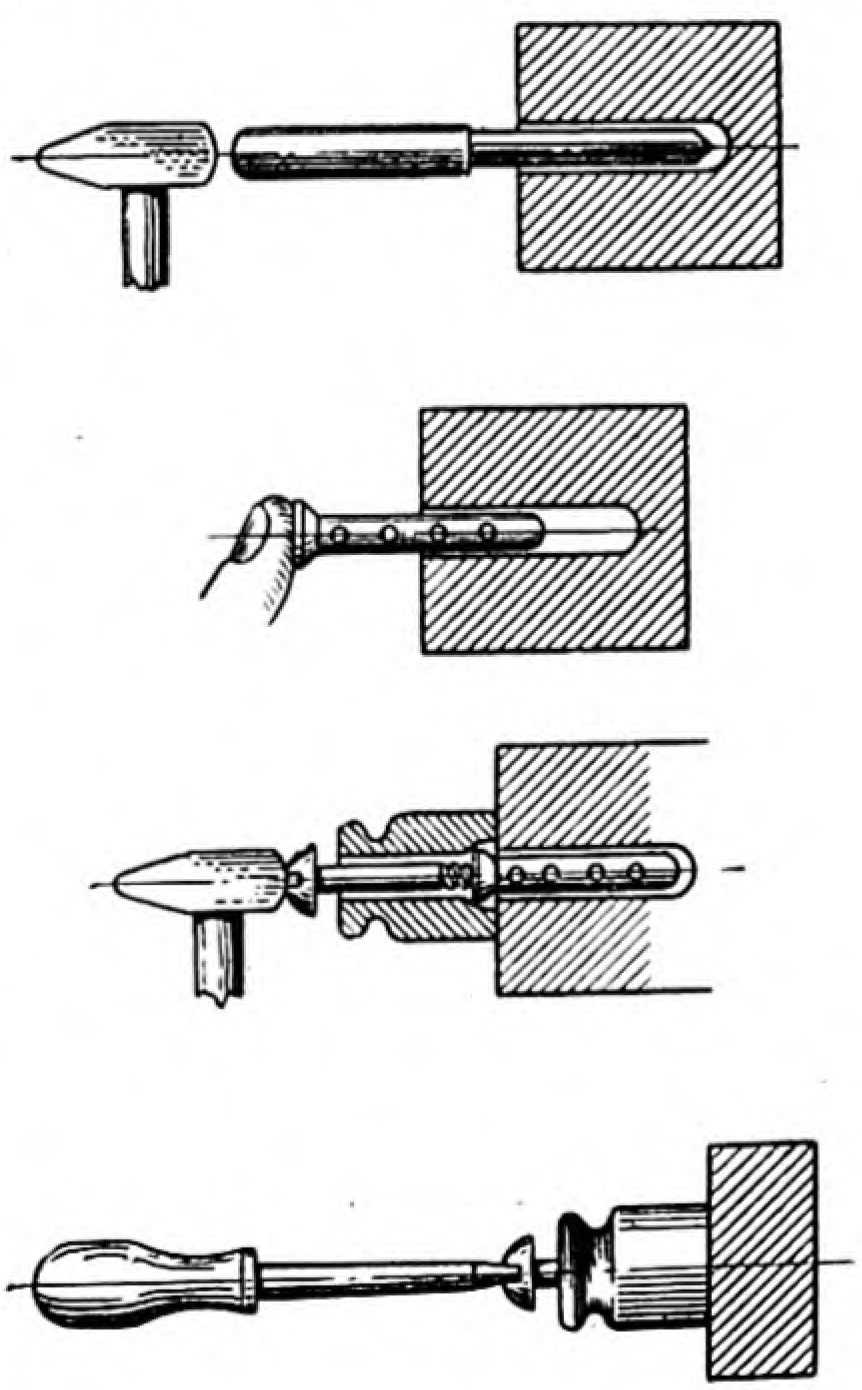


Fig. 95. Knob insulator fixing with a dowel plug.

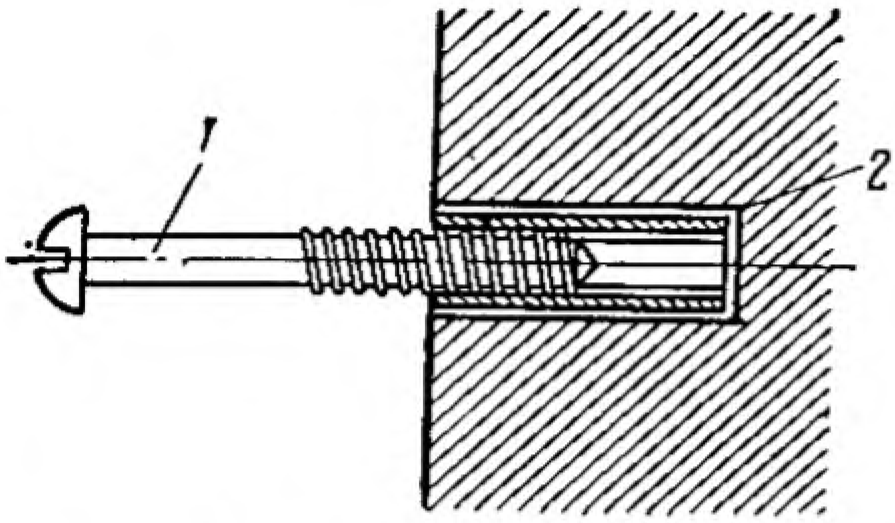


Fig. 96. Screw driven into rolled piece of p.v.c. tubing to fix a knob insulator:
1—fixing screw, 2—rolled p. v. c. tubing.

rolled p.v.c. tubing. As the screw is driven in, the tubing expands, is tightly jammed against the hole in the wall and thus securely holds the screw in the hole (Fig. 96).

For screws 4.5 mm in diameter, the hole is bored with 5.2 to 5.5 mm diameter drills and the tubing is 5 to 6 mm in diameter. The size of the drill for screws of other diameter should not exceed screw diameter by more than 0.6 to 1 mm.

Where grade ПРД (PRD) twisted-pair wire is run concealed for passage in through holes and under obstacles, it is passed through one common piece of insulating tubing (Fig. 97).

When grade ПРД (PRD) twisted-pair wire must be jointed to solid-conductor wire where the wiring passes from a dry-atmosphere room to a wet-atmosphere room, or to the outdoor atmosphere, the joint must be located only within the confines of the dry-atmosphere room.

Before installing grade ПРД (PRD) wire, the length of the wire is first measured off in accordance with the circuit section to be put in.

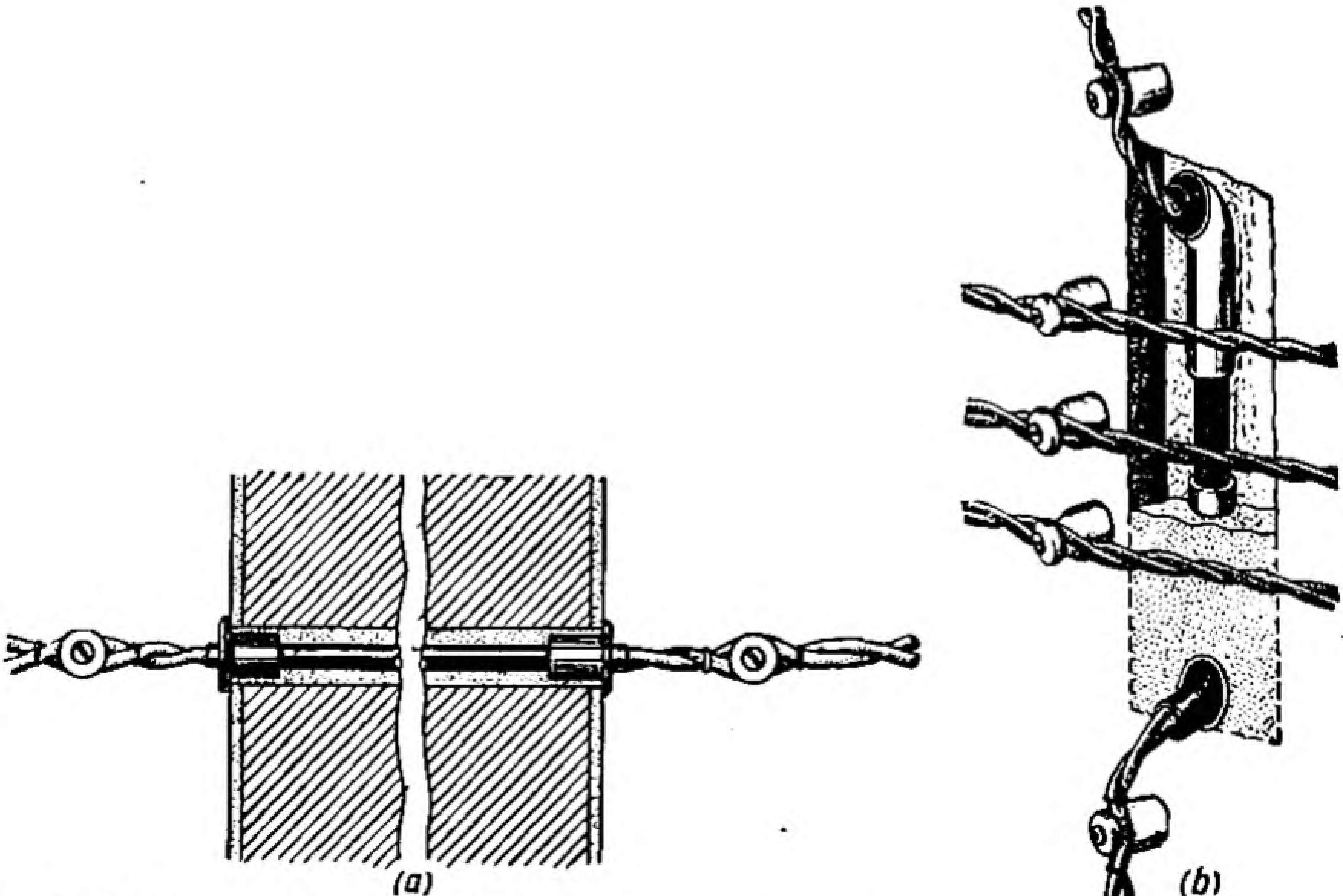


Fig. 97. Passage of grade ПРД (PRD) wire through holes and under obstacles
a—through-hole passage, b—passage under obstacle.

After the length of the wire or a given run has been measured off, the end of this length of wire is tied to the last knob insulator at any one end of the run (Fig. 98). Following this, the wire is pulled taut up to the first point at which it must be tap jointed, marked and cleaned off for jointing.

Both splices and tap-off joints in this grade of wire are made by the compression method (Fig. 99).

To make a splice in grade ПРД (PRD) wire, the braided-cotton sheath is forced backward from each end of the wire and the rubber insulation is removed over a length of 15 to 20 mm, care being taken not to damage the thin strands of the wire. The skinned ends of the wire are next fanned out and thoroughly cleaned bright with a knife following which the ends to be spliced are lightly twisted one about the other and served with a wrapping of copper foil. The splice can then be completed with the compression-jointing tongs.

After the above operations have been completed, the braided-

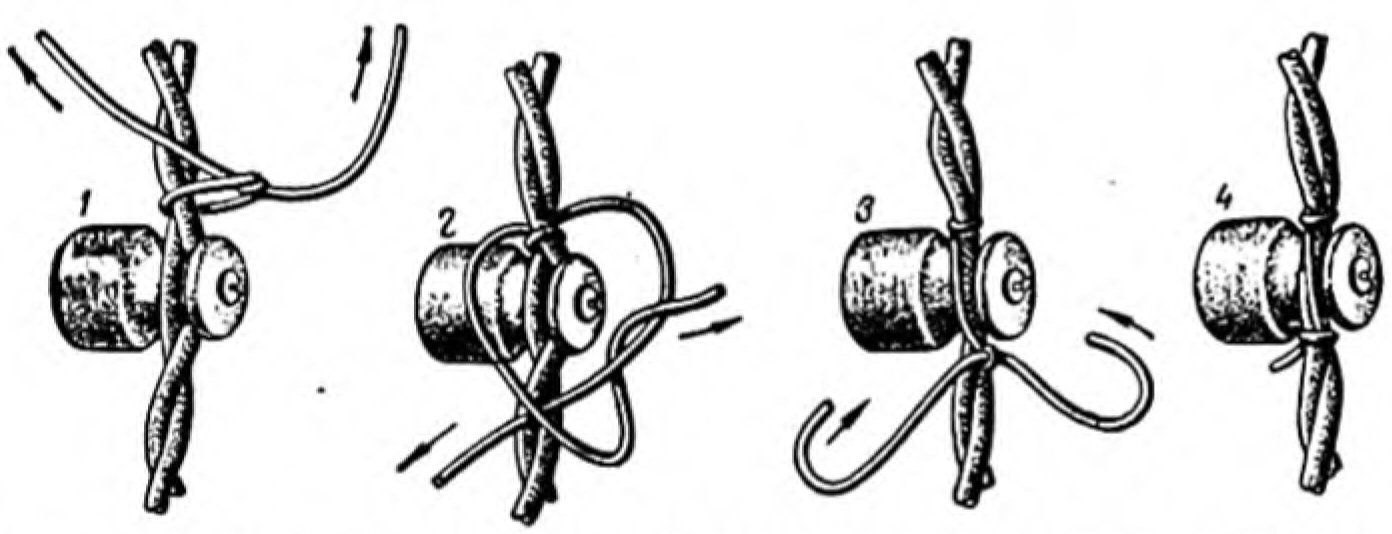


Fig. 98. Tying grade ПРД (PRD) wire to a knob insulator:
1, 2, 3, 4—sequence of operations

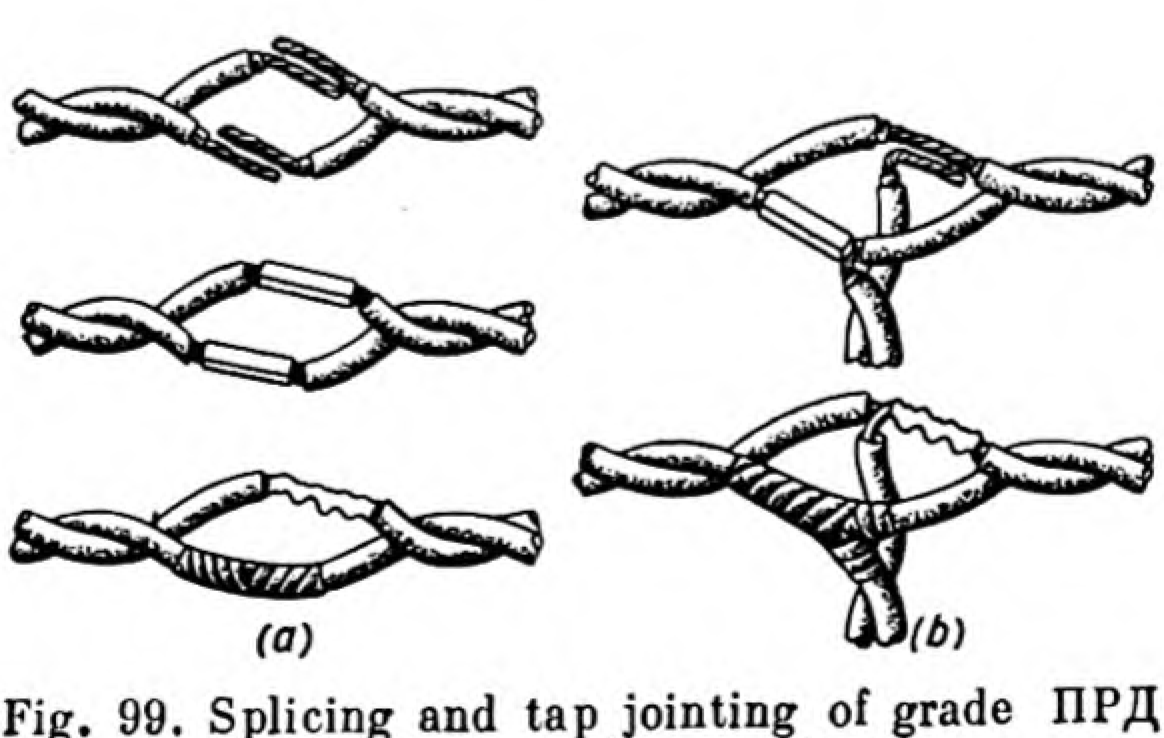


Fig. 99. Splicing and tap jointing of grade ПРД (PRD) twisted-pair wire:
a—splice, *b*—tap joint.

cotton sheath ends are shifted back over the splice and two layers of insulating tape are applied to complete the joint.

To install wiring with grade ПРД (PRD) wire it is almost always necessary to add one or two conductors to the main twisted pair. For this, a necessary additional length of grade ПРД (PRD) wire must be untwisted and one of its conductor rope-lay wound on to the two main conductors (Fig. 100) when three conductors are needed.

If two conductors must be added, it is possible to wind them on without untwisting into two separate conductors (Fig. 101).

When grade ПРД (PRD) wire is being installed, it is often necessary to know exactly what position a given conductor occupies at a given point. Since the conductors are twisted one about another, it becomes difficult to distinguish the given conductor from the others. To find such a conductor, a so-called "identifying loop" can be tied around the given conductor as shown in Fig. 102 in order to make it possible to find the position of the conductor at a given point by shifting the loop along the twisted wire.

After all the conductors of a given run have been spliced, tapped-off and twisted on, the wire can be pulled taut and tied

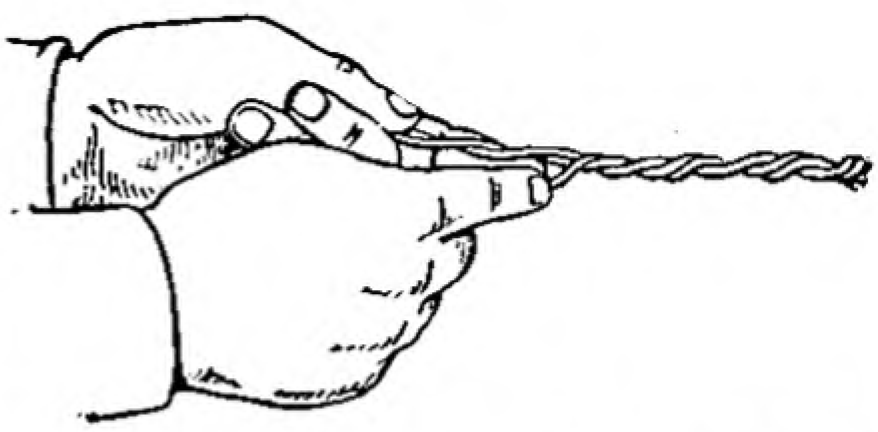


Fig. 100. Twisting on of one additional conductor.

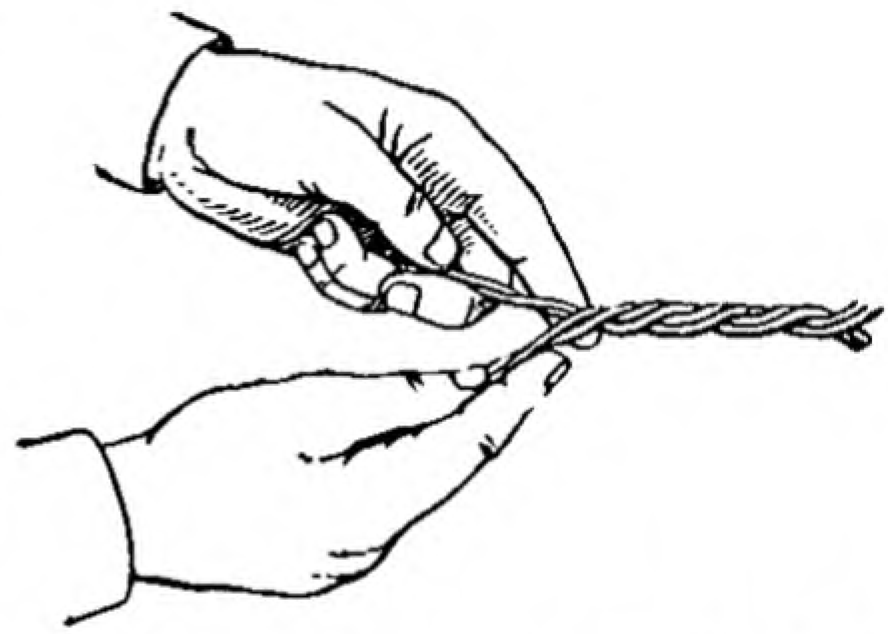


Fig. 101. Twisting on of two additional conductors.

to the other far-end knob insulator.

When slipping the wire over the heads of the intermediate knob insulators, it is necessary to start from the knob insulator nearest to the middle of the run so as to obtain uniform tension in the wire along the entire run. Grade ПРД (PRD) wire is to be tied to the knob insulators at the ends of runs, at the corner turns, to the knob insu-

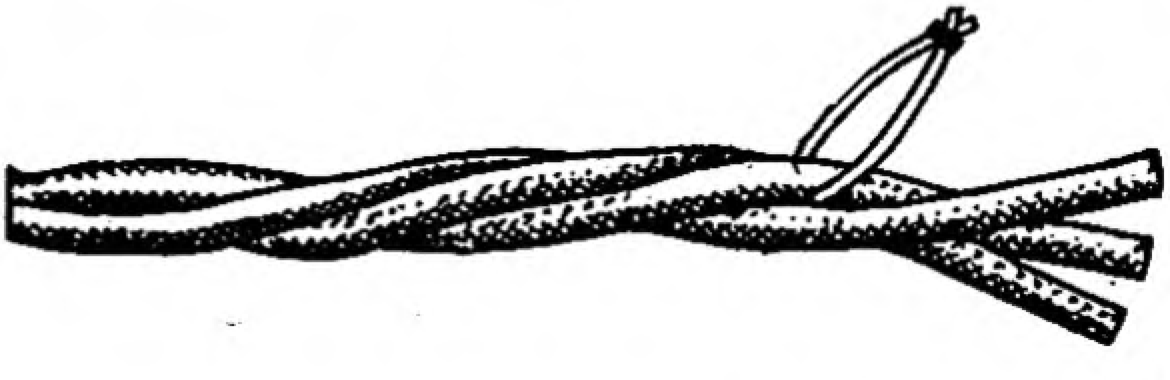


Fig. 102. "Identifying loop" tied around a conductor of grade ПРД (PRD) wire.

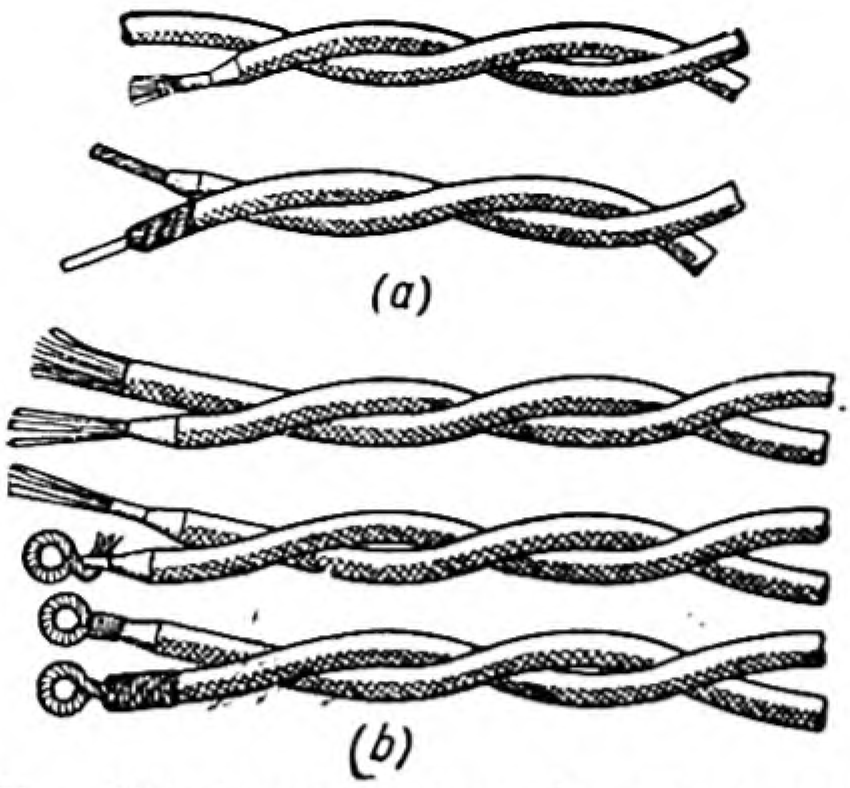


Fig. 103. Terminating of grade ПРД (PRD) wire:
a—stub end, *b*—ring end.

lators where the wires enter or leave a section concealed for passage under an obstacle, and where the wires pass from one plane surface to another, and also to the knob insulators at which the conductors are spliced or tapped.

The lighting fittings to be installed in conjunction with such systems of wiring must generally be first fitted with internal hook-up wiring before being hung in place. To keep them out of sight, the connections made to lighting fitting leads are stowed in the ceiling rosettes of the fittings.

Where grade ПРД (PRD) wire is connected to lighting switches, plug sockets and other devices, it is terminated by twisting the ends of the conductors to form either a stub end (Fig. 103*a*) or a ring (Fig. 103*b*).

Both stub and ring ends must be tinned. This reliably joins the separate strands of the conductor together. If this is not done, the strands may be damaged or broken when the terminal screw or nut is fully screwed down. Tinning likewise prevents the conductor from becoming oxidised at the points of connection.

Task. Knob wire an office room in an industrial works with 1.5 sq mm grade ПРД(PRD)

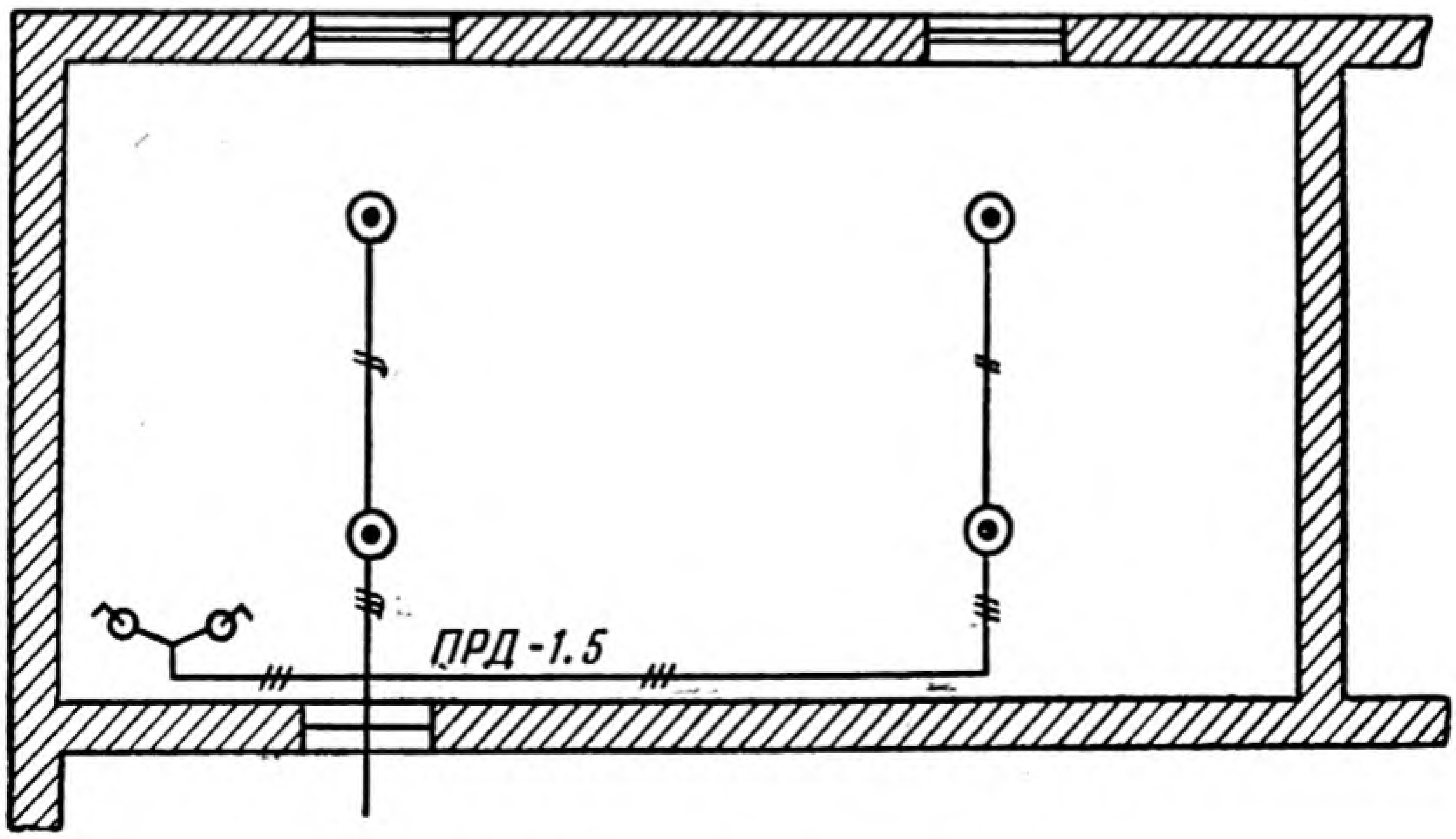


Fig. 104. Wiring floor plan.

twisted-pair wire. A plan of the room showing the layout of the wiring is given in Fig. 104. The scale of the drawing is 1 : 100 and the height of the room is 3 m.

Answer by doing the following:

1) draw a full-line diagram showing how the lamps are controlled by two lighting switches;

2) explain what operation sequence is followed in performing the job;

3) draw up a bill of materials for the job, and list the necessary tools and appliances.

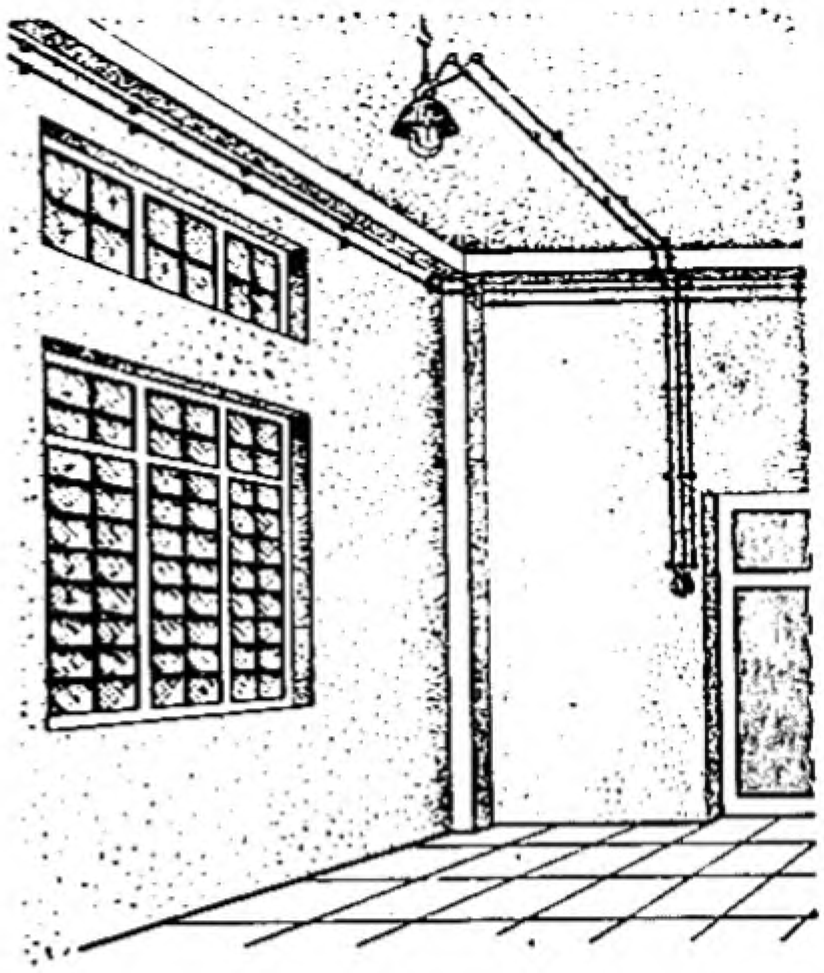


Fig. 105. General appearance of wiring installed with wires supported on pin-type insulators.

4. Installation of Wires on Pin-Type Insulators

Wiring is installed on pin-type insulators in moist (moisture-laden), wet and hot premises, and also out-of-doors.

A general pictorial representation of such wiring is shown in Fig. 105.

Laying out and Marking off. The places where the lighting fittings, lighting switches and plug sockets are to be mounted must first be laid out and marked off in the same way as for knob wiring.

Examples showing how the lines are marked off for installing wires on pin-type insulators fixed with the aid of gooseneck hooks, and with double-hook and single-hook anchors are given in Fig. 106.

Table 16

Spacings for Installation of Wiring on Pin-Type Insulators

Distance between centres of supports	Spacing (in mm) for wires of following size (sq mm)				
	1.5-2.5	4-10	16-25	35-70	95-120
Minimum transverse spacing	70	70	100	150	150
Maximum space between supports along line of wire	2,000	2,500	3,000	6,000	6,000

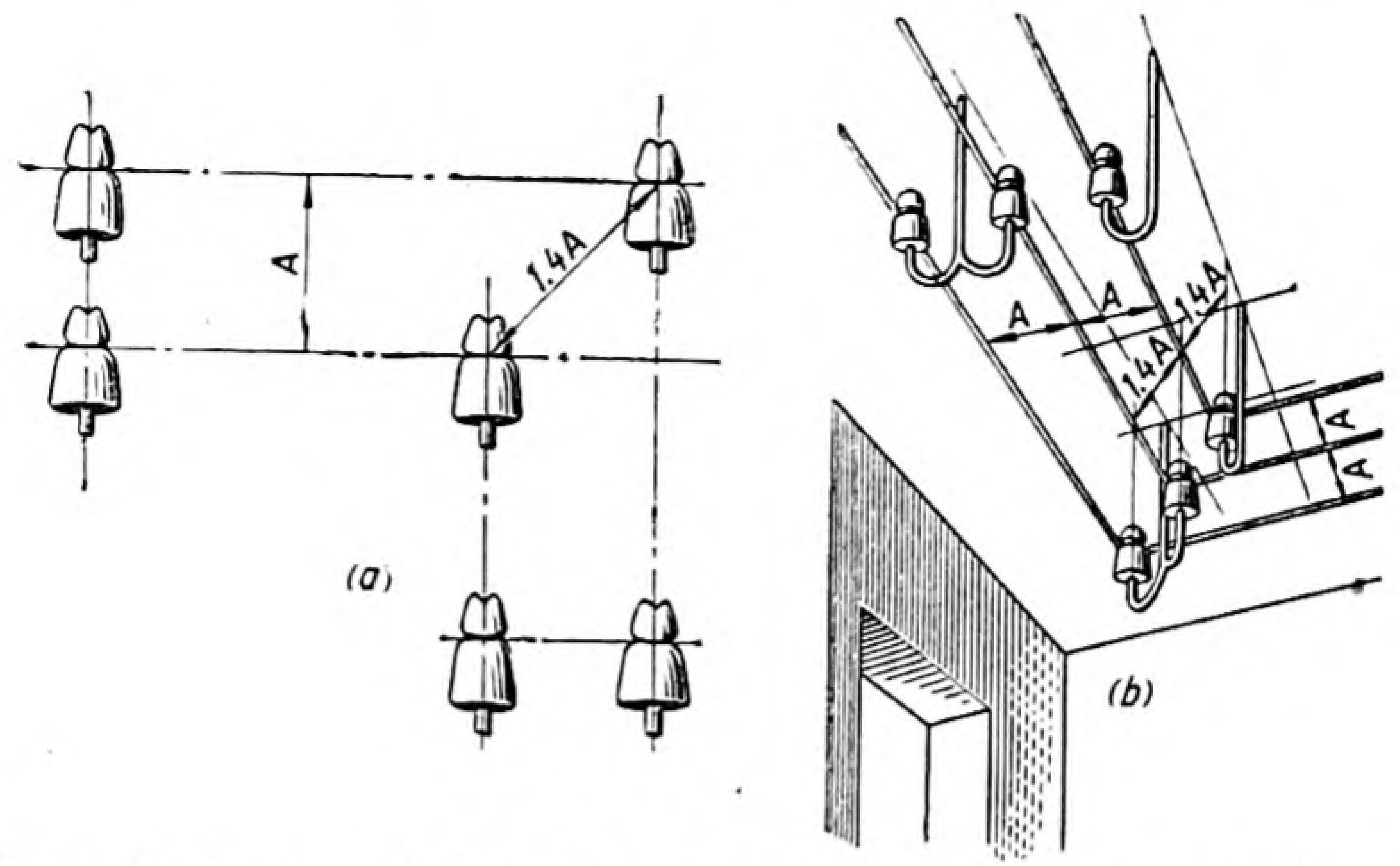


Fig. 106. Layout of lines in marking off pin-insulator supported wiring:
a—for gooseneck hook fixing to walls, b—for double- and single-hook anchor fixing to ceilings.

The spacings to be observed in laying out lines of such wiring are listed in Table 16 (p. 97).

Preparatory Work. Pin (petticoat)-type insulators are usually secured on their gooseneck hook, double-hook anchor or single-hook anchor supports by first serving a wrapping of impregnated tow round the end of the hook or anchor support and then screwing the insulator down over this wrapping. The tow is impregnated with a mixture of red lead in boiled linseed oil. This operation is performed with the support hook or anchor clamped in a vise. The tow, in thin strands, must be wound tightly round the roughened surface of the hook or anchor end to ensure that the wrapping will not be able to turn on the hook or anchor.

The layers of tow should be applied to give the wrapping a barrel-like shape, the thickest portion of the wrapping being wound to a diameter of 2 to 3 mm greater than the inside diameter of the threaded hole in the insulator to be fitted.

A small wad of tow must be pushed down to the bottom of the threaded blind hole in the insulator. This wad serves to protect the insulator from injury by the end of the gooseneck hook, double-hook anchor or single-hook anchor on which the insulator is subsequently screwed down.

If during the final part of this fitting process the end of the metal hook or anchor comes into contact with the internal surface of the insulator head, the insulator should be screwed backward through a half-turn to avoid destructive mechanical stresses in the porcelain during possible subsequent rises in temperature.

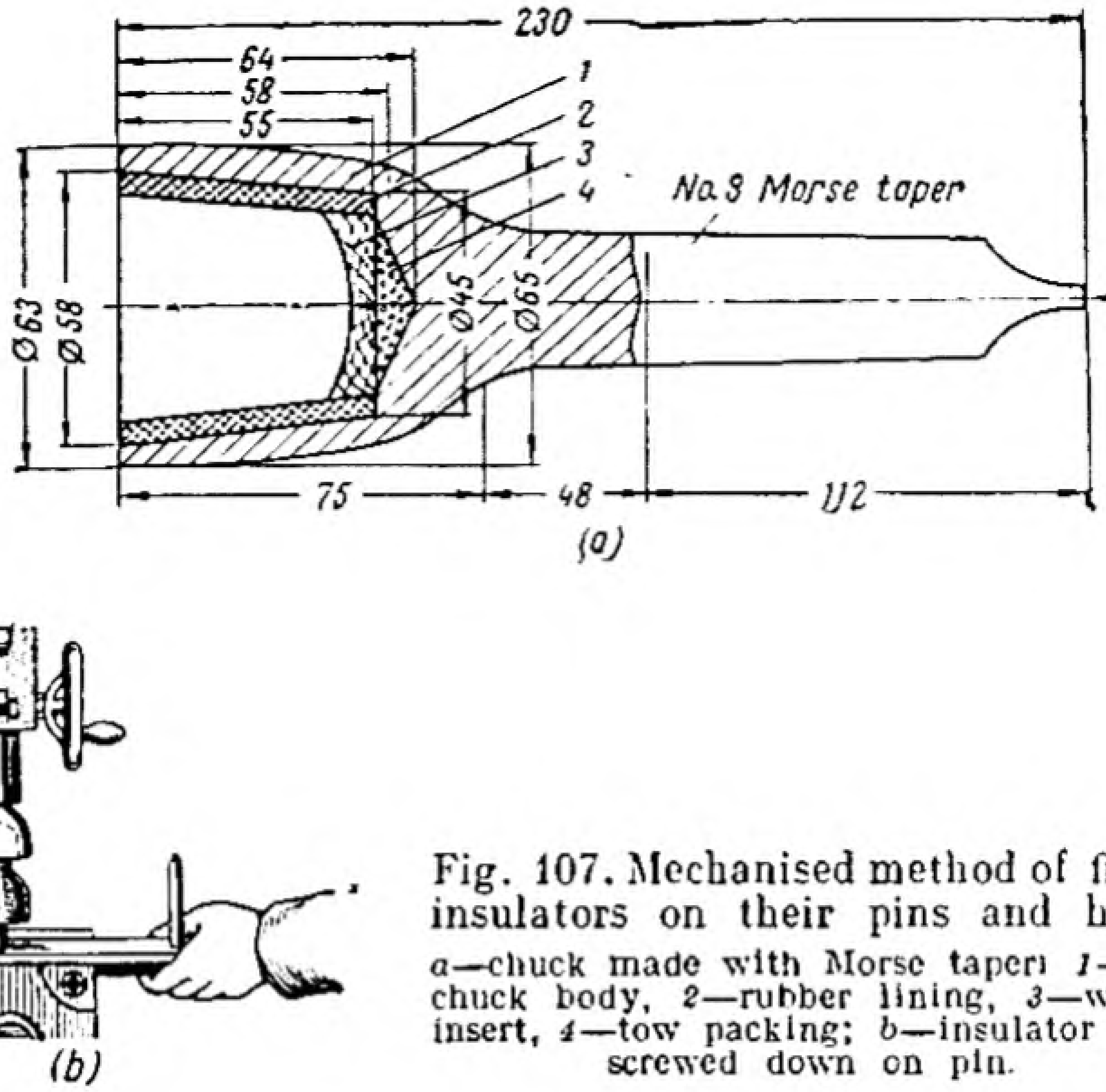


Fig. 107. Mechanised method of fitting insulators on their pins and hooks:
a—chuck made with Morse taper: *1*—steel chuck body, *2*—rubber lining, *3*—wooden insert, *4*—tow packing; *b*—insulator being screwed down on pin.

In cases when very large numbers of insulators must be fitted on their supports, the work can be mechanised by using a special fixture in the form of a steel chuck machined with a Morse taper tang (Fig. 107*a*). This chuck has its internal walls lined with rubber held in place by a wooden insert with tow packed between its bottom and the body of the chuck.

This fixture is secured in the spindle of a hand-operated drilling machine, lowered on to the head of the insulator, and screws the insulator down when the spindle of the machine is turned (Fig. 107*b*). For this, the insulator is set on the end of the hook (or straight pin) with the hook (pin) clamped in the vise of the drilling machine. The hook or straight pin, as usual, is first prepared by applying a tow wrapping impregnated with a red lead and linseed oil cementing compound.

Small-size pin insulators are usually fitted on their supports by a different method, their internal threaded space being filled with a mortar consisting of one part of cement and two parts of sand. Since such mortars harden only after 7 to 8 days, setting is accelerated by adding water glass in the ratio of one litre per pail.

The fitted insulators, before the mortar begins to set, are placed in a box filled with sand as shown in Fig. 108.

When insulators are fitted with gooseneck hook supports, care must be taken to see that the horizontal fixing-end axis of the hook falls in line with the centre of the neck groove in the insulator. If this is not observed, the

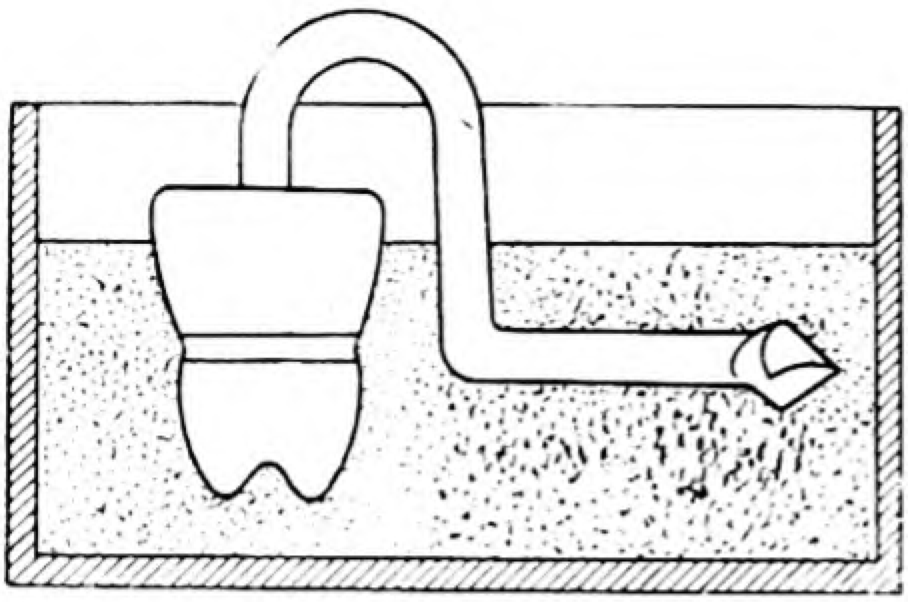


Fig. 108. Sand box used in fitting insulators with cemented-in hooks or pins.

entire assembly will lack stability when mounted.

Insulators fitted with gooseneck hooks or hook anchors are fixed to wooden surfaces by being screwed directly into holes prepared for them by drilling with a gimlet.

Insulators fitted with straight pins are installed with the aid of support stirrups or crossarms, which are fixed, if the surface is wooden, by means of wood or lag screws.

In brickwork and concrete surfaces the fixing holes required for installing the insulators are either drilled with an electric drill or driven with a pneumatic hammer. In cases where the amount of work to be done is small in volume, the holes can be driven with hand tools such as a chisel and hammer. If the insulators are fitted with gooseneck hooks or hook anchors, the diameter of the hole is made equal to three times hook or anchor shank diameter. The depth of a hole for a gooseneck hook is made so as to receive the entire length of its tail end; for double-hook and single-hook anchors the depth of the hole must equal one-third of the length of the tang part.

Holes of square shape are driven for anchoring the "legs" of stirrups used to support the insulators, the side of the square being made twice the stirrup-leg width. The hole is driven to a depth of at least one-third of "leg" length.

Before gooseneck hooks, double- and single-hook anchors and stirrups can be cemented in, the holes must be thoroughly cleaned and wetted with water. After being placed in the holes, the hooks, anchors or stirrups are anchored with cement mortar (made by mixing one part of cement and three parts of sand).

Heavy stirrups are installed by setting them in their fixing holes, aligning them with a plumb line and spirit level, and temporarily "freezing" them in place with plaster of Paris mortar. Following this, the holes are filled with cement mortar to which small pieces of crushed brick are added. The stirrups are again aligned if necessary and then left untouched until the mortar fully sets.

First to be installed in pin insulator wiring are the individually supported insulators or stirrup-mounted sets of insulators (Fig. 109) which must be placed at the ends of the runs. After this, a guide string can be stretched between the end insulators for properly aligning the intermediate supports.

Through Hole and Groove Work. At through holes where

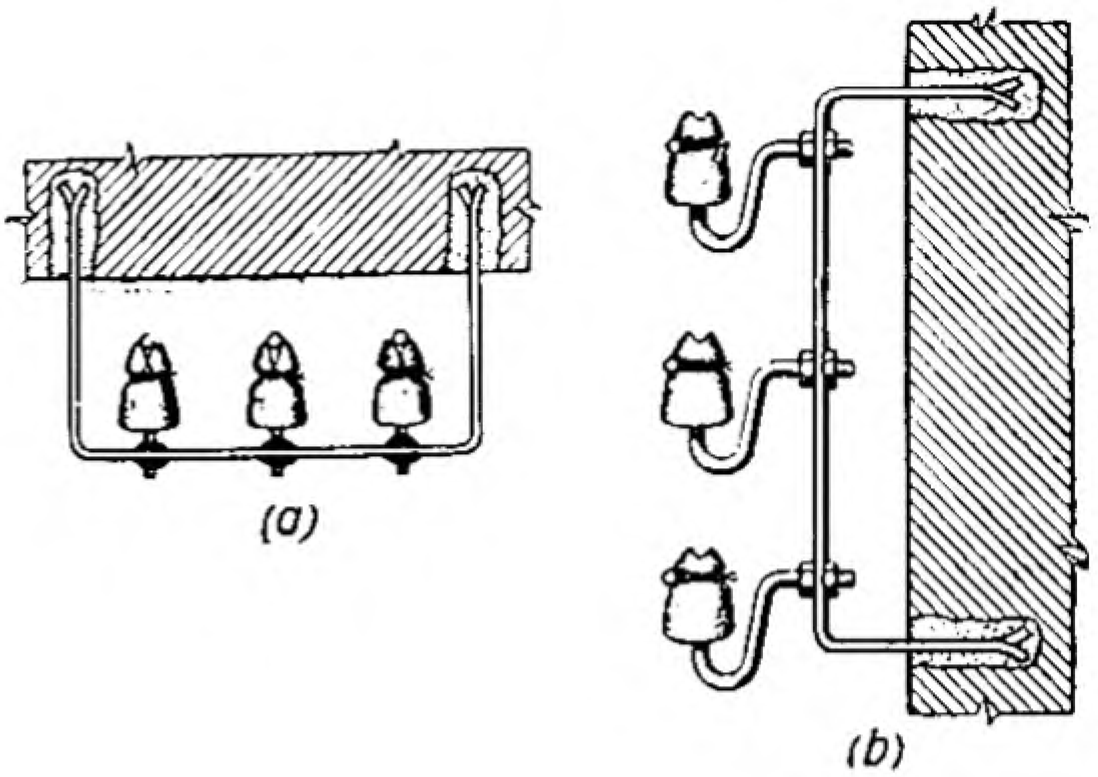


Fig. 109. Stirrup-mounted sets of pin insulators cemented in place:
a—fixed to ceiling; b—fixed to wall.

such wiring must go through a wall, each wire must be individually protected by a piece of semihard rubber or p. v. c. tubing. In wet and hot premises, glass tubing, or more rarely, porcelain tubing is used instead of rubber or p. v. c. tubing. The ends of the tubing where the holes reach a wall surface are fitted with bent porcelain tubes. The latter have their openings sealed at the funnel-end with an insulating compound such as, for example, bitumen cable compound, or powdered porcelain mixed with water glass.

Wire Installation. When the wires are installed, they can be tied to the intermediate insulators either in their head or in the neck grooves. At the insulators on which the runs make a turn the wires are tied or secured by a dead-end type loop (Fig. 110) only round the neck groove.

Mounting of Lighting Fittings, Lighting Switches and Plug Sockets. Where wiring is installed on pin-type insulators, the lighting fittings are mainly of a type suitable for damp premises (Fig. 111), or are of the dust-and-water-tight type.

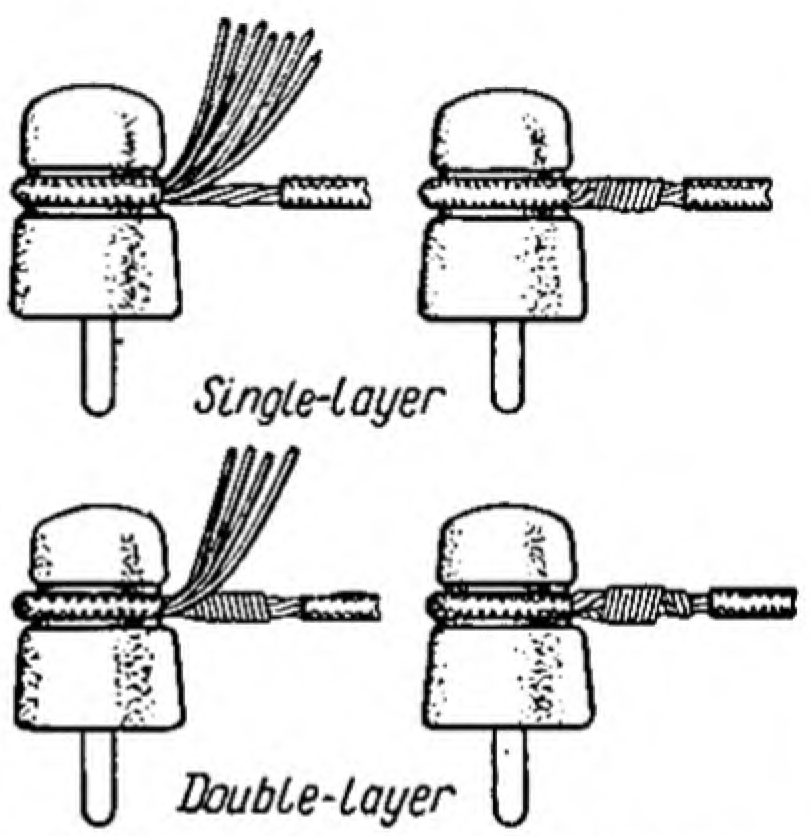


Fig. 110. Dead ending of wires in pin-insulator wiring.

For this kind of wiring hermetic-type lighting switches and plug sockets are used.

Task. A shop must be wired with 2.5 sq mm grade ПР-300 (PR-300) rubber-covered wire installed on pin-type insulators. A plan of the shop showing the layout of the wiring is given in Fig. 112. Explain the sequence

the work and give a list of the necessary tools and appliances. The drawing has a scale of 1 : 100 and the room is 3 m high.

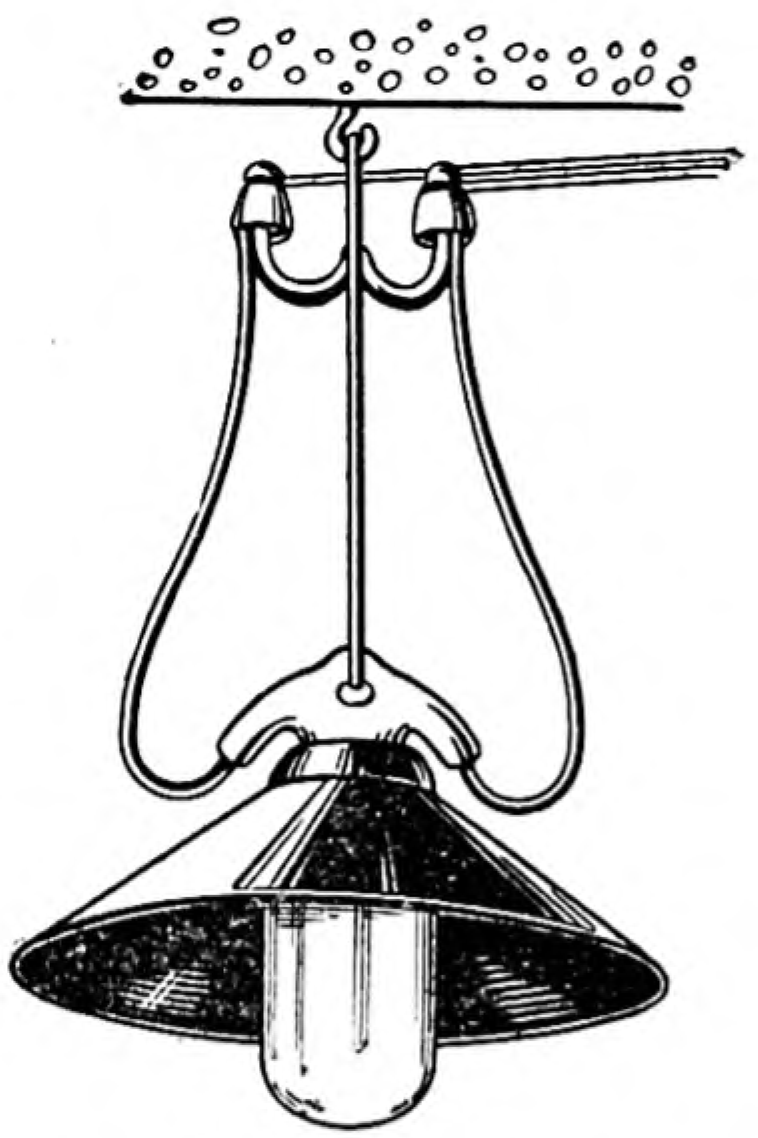


Fig. 111. Lighting fitting installed in damp premises having pin-insulator supported wiring.

of operations which must be followed to perform the job, draw up a bill of materials for

5. Wiring with Grade ТПРФ (TPRF) Wire

Grade ТПРФ (TPRF) lock-jointed steel-sheath wire can be used to wire dry normal-atmosphere rooms for voltages up to 500 volts. The general view of such wiring is illustrated in Fig. 113.

Laying out and Marking off. This type of wiring must be installed so that the lines of wiring follow the general architectural lines of the premises. If grade ТПРФ (TPRF) wire is fixed with straps, marking off of the lines must conform with the strap-hole centre lines (Fig. 114*a* and *b*).

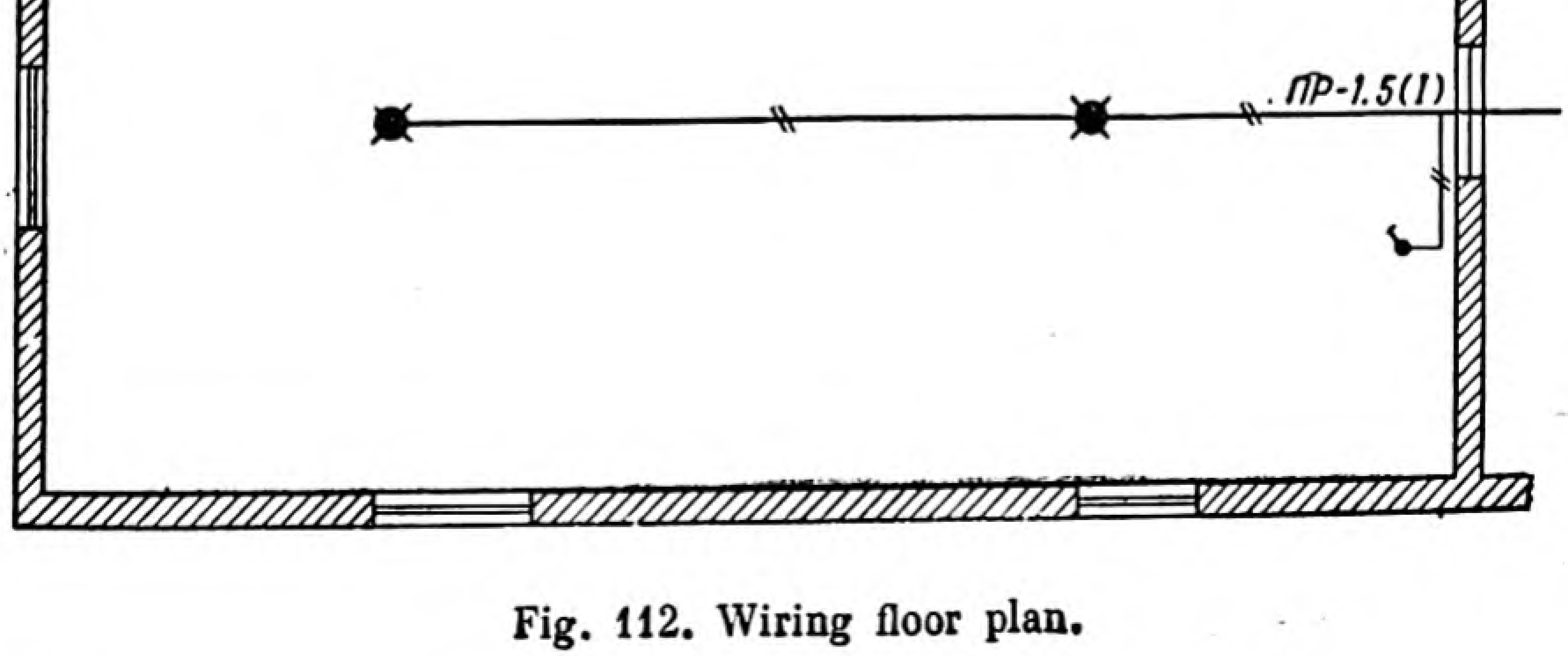


Fig. 112. Wiring floor plan.

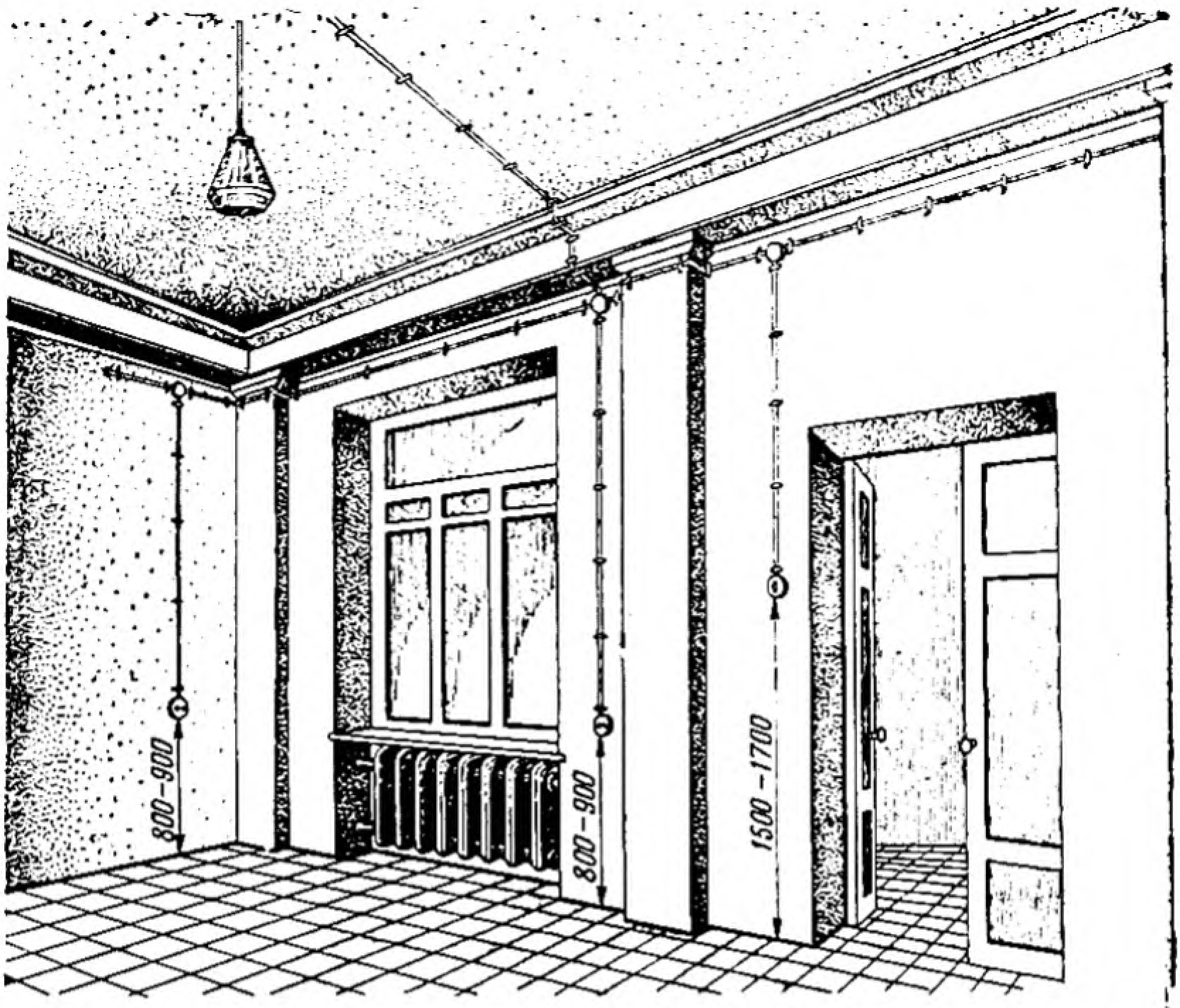


Fig. 113. General appearance of wiring installed with grade ТПРФ (TPRF) wire.

Marking off is done in one line when the wiring is fixed with clips.

Spacings between the fixing straps or clips along the wire should not exceed 500 mm. When the place for a fixing part is marked off at through hole passages, the distance from the strap or clip centre to the centre of the through hole should range from 50 to 60 mm. The centre of the fixing strap at a junction box must not be more than 85 mm from the centre of the junction box.

The bends made in grade ТПРФ (TPRF) wire in going through turns and running under obstacles must have a radius of not less than six diameters of the wire; the fixing straps or clips should be placed at both sides of the bend, at its beginning and at its end (Fig. 114*c*).

Preparatory Work. Straps are fixed on wooden surfaces with round-head wood screws; in case of brickwork and concrete, plug dowels or wire-spiral anchores are employed for this purpose.

One of the methods widely used today to secure grade ТПРФ (TPRF) wire to brickwork and concrete surfaces is buckle clip fixing (see Fig. 115). The

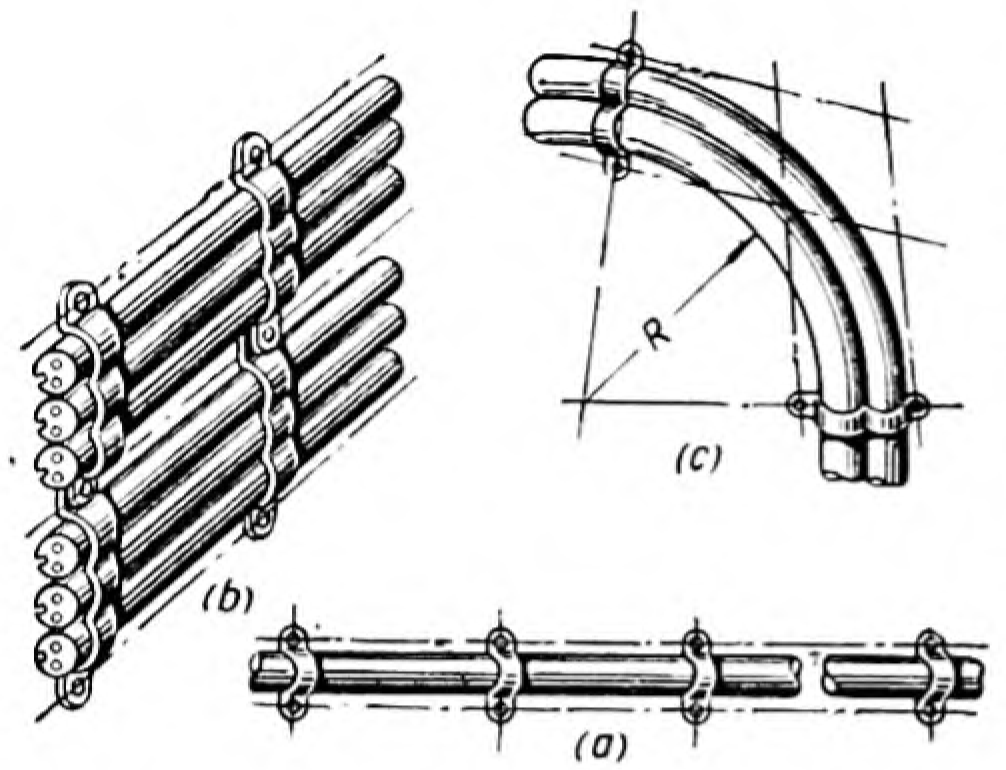


Fig. 114. Layout of runs for wiring with grade ТПРФ (TPRF) wire:
a—for single-wire run, b—for six-wire run, c—at a turn in a run.

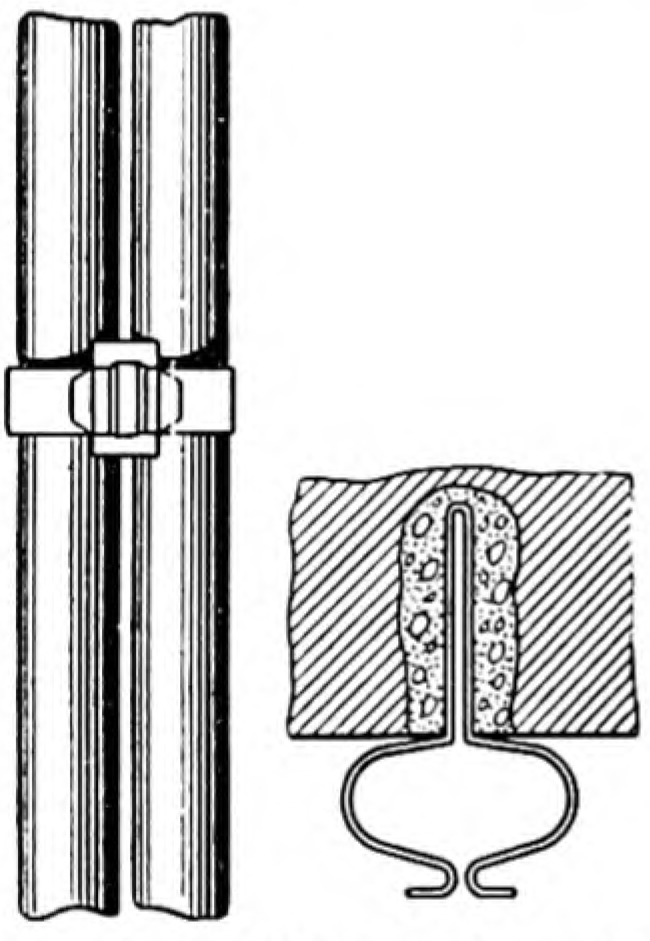


Fig. 115. Fixing of grade ТПРФ (TPRF) wire with buckle clips.

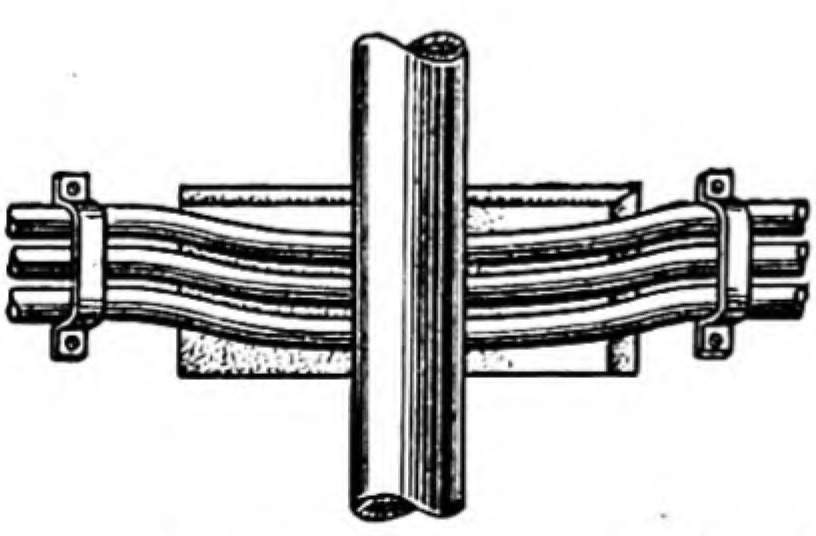


Fig. 116. Method of passing obstacle in ТПРФ (TPRF) wire installation.

clips are made from tin plate or sheet aluminium 1 to 1.5 mm thick cut into strips from 5 to 6 mm wide.

Grade ТПРФ (TPRF) wire is run directly through the holes made in wooden walls for its passage, porcelain or moulded-plastic bushings being first inserted into both sides of the hole to give the wiring a more finished appearance.

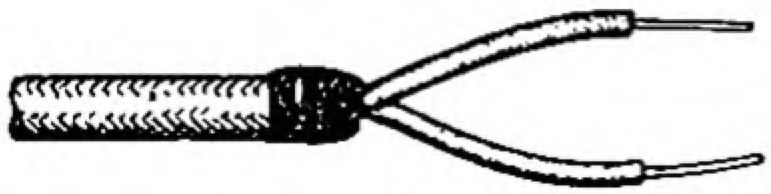
Where grade ТПРФ (TPRF) wire must be passed through brick or concrete walls, the hole must be fitted with an appropriate piece of conduit pipe.

This type of wire must be protected by steel conduit pipe to a height of at least 2 metres above floor level when the wiring must pass through a floor structure.

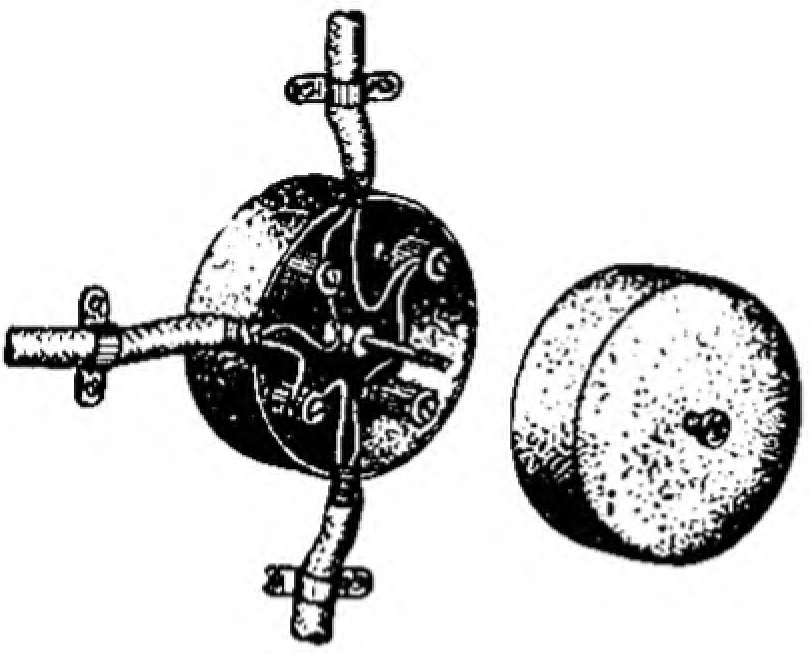
To pass under obstacles when installing grade ТПРФ (TPRF) wire, the wiring is laid in by providing an open plastered groove under the obstacle (Fig. 116).

Wire Installation. The wire must first be unreeled. As it is unreeled, it is straightened with a hand straightening device or by drawing it through a bench-type roller straightener. The straightened wire can then be temporarily run in under the fixing straps with the seam facing the wall and secured in several places. Where the wire has to be run through holes, it must be pulled through before fixing is commenced.

To make bends in this type of wire, special bending tongs or pliers are required.



(a)



(b)

Fig. 117. Connecting grade ТПРФ (TPRF) wires:
a—termination dressing of wire, b—wire brought into box.

With the wire temporarily in place, the ends at the junction boxes are measured off for a length suitable for connection and tapping, following which, after off-set bending of the ends as shown in Fig. 117*b*, terminating of the wires is begun. For this, the unnecessary length of protective steel sheathing is removed by notching the joint and unfolding it. When removing the sheathing remember that the length must be just enough to enter the junction box by about 3 to 4 mm.

A banding of unbleached twine or insulating tape (preferably of adhesive p.v.c. tape) is then applied to a distance up to 10 mm from the edge of the metal sheath, after its burrs have been removed. The width of this banding is from 8 to 10 mm (Fig. 117*a*).

After the banding has been put on, the belt insulation can be removed, the wires led into the box and the conductor ends cleaned and either connected to the terminals or spliced by compression jointing.

When the installation work at the boxes is completed, the wire is permanently fixed, straightening of the runs of wire being carried out simultaneously with final fixing.

Mounting of Lighting Fittings, Lighting Switches and Plug Sockets. Before finally securing the ends of wire run to lighting fittings, switches and plug sockets, the wire must be finish terminated. If ТПРФ (TPRF) wire is directly led into the lighting fitting, switch or plug socket, it is terminated in the same manner as when brought in at a junction box. When the wire end cannot be directly brought in, a terminating collar (Fig. 118) is fitted over the

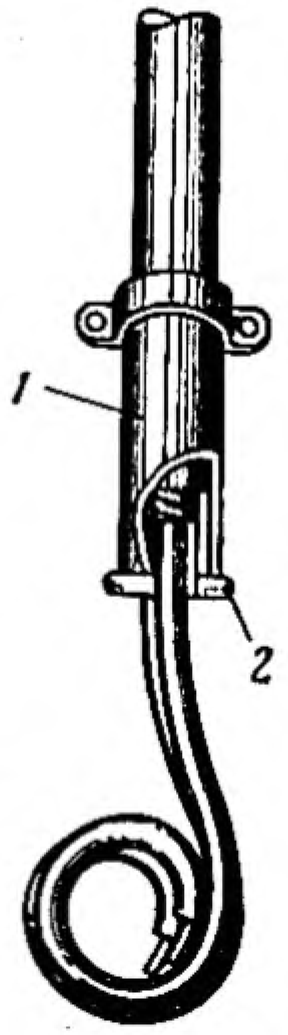


Fig. 118. Finish dressing of ТПРФ (TPRF) wire with a terminating collar:
1 — terminating collar, 2 — bushing.

dressed end of the wire to give it a finished appearance.

Lighting circuits wired with grade ТПРФ (TPRF) wire use opal-glass pendant fittings such as the "Lutsetta" or "Shar" (ball) pendents, and also rosette-mounted ceiling and wall lighting fittings.

When the connections are made to lighting fittings suspended from a ceiling hook, the ends of grade ТПРФ (TPRF) wire are concealed behind the ceiling plate; where the connections are made to lighting fittings mounted upon wooden rosettes, the connected ends are concealed under the body of the fitting itself.

Lighting switches, plug sockets and devices of a like nature are mounted in the usual way for ТПРФ (TPRF) wiring.

Task 1. Show how to mark off a two-wire run of wiring installed with grade ТПРФ (TPRF) wire fixed with straps and passed over an obstacle in the form of a projecting beam surface (Fig. 119).

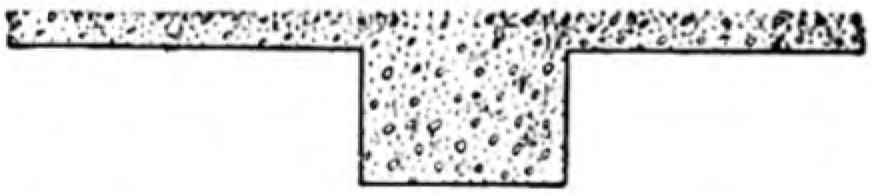


Fig. 119. Beam-surface obstacle to be gone around by wiring.

Task 2. Draw up an operation-sequence card for the installation of size 2×1.5 sq mm ТПРФ (TPRF) wire to be run through an overhead floor structure of concrete construction and show how to mark off and drive the through hole, install the protective steel conduit pipe and pull the wire through the pipe.

6. Wiring with Lead-Covered СРГ (SRG) and P.V.C.-Covered ВРГ (VRG) Rubber-Insulated Cables *

Grade СРГ (SRG) and ВРГ (VRG) cables are used to wire circuits for voltages up to 500 volts within dry normal-atmosphere, damp and wet premises. The general appearance of wiring installed with these kinds of cables is shown in Fig. 120.

Laying out and Marking off. The laying-out and marking-off work to be performed in installing СРГ (SRG) and ВРГ (VRG) cables is identical to that done with grade ТПРФ (TPRF) wiring. However, due to the more elastic construction of these grades of cable, smaller layout spacings are required. Thus, the fixing straps must be spaced on horizontal runs at intervals up to 400 mm when installing СРГ (SRG) cables and at intervals up to 300 mm when installing ВРГ (VRG) cables; on vertical runs the intervals may be up to 500 mm for СРГ (SRG) and up to 400 for ВРГ (VRG) cables. When ВРГ (VRG) cables are installed on ceilings,

* Wiring with grade НРГ (NRG) and АСРГ (ASRG) cables is not discussed since it is identical to wiring with grade СРГ (SRG) and ВРГ (VRG) cables.

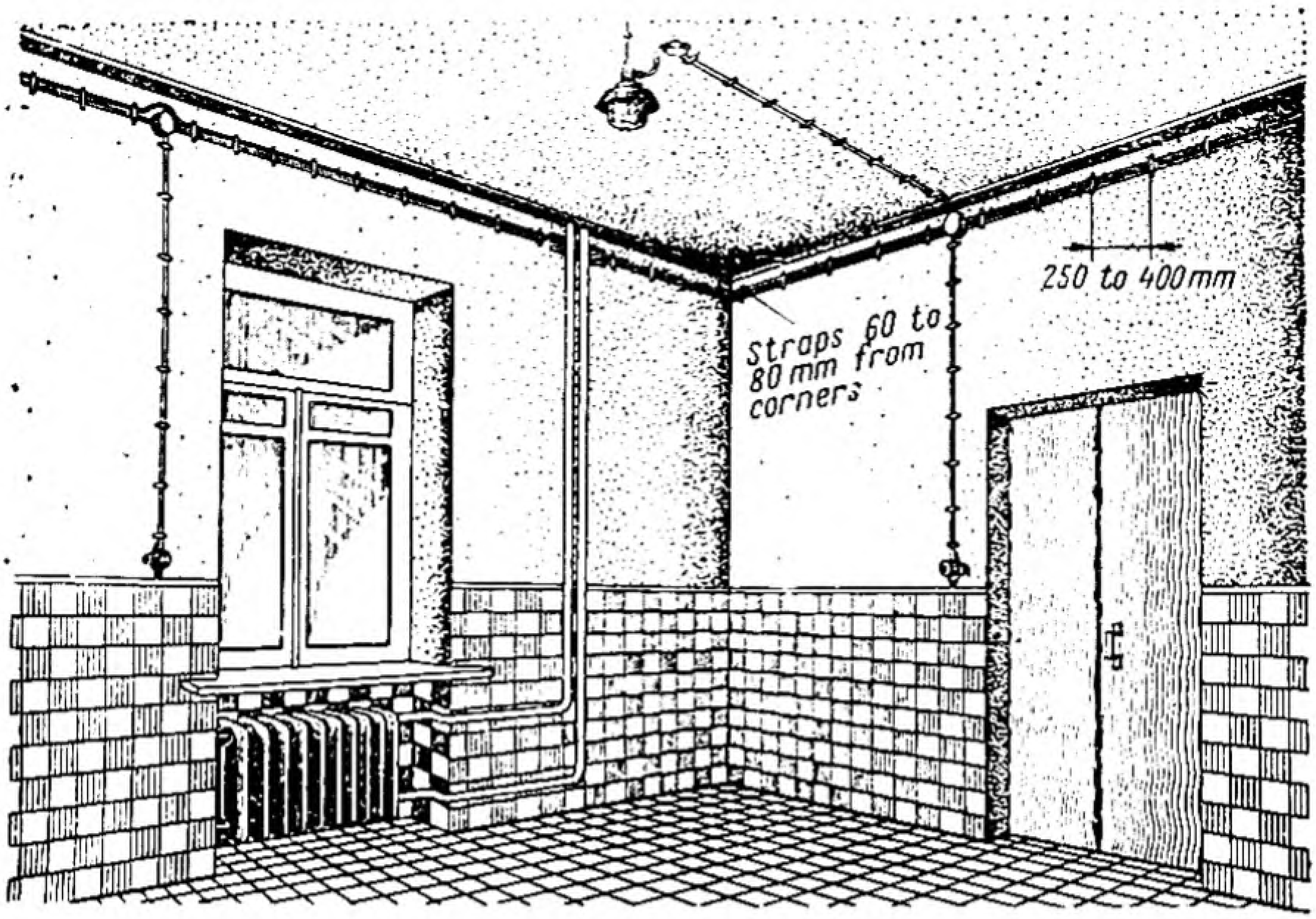


Fig. 120. Appearance of wiring installed with lead-sheathed grade СРГ (SRG), or vinyl-sheathed ВРГ (VRG) cables.

the fixing straps should be spaced at intervals not greater than 250 mm; with longer spacings the cable will tend to sag between straps.

The distance to the centres of the closest fixing straps from the centre of a junction box for the above kinds of cables should range from 100 to 120 mm; the distance from the centre of a through hole to the centre of the closest fixing strap should equal 70 to 80 mm.

At turns and passages over obstacles the radius of bends in СРГ (SRG) cable should not be less than 9 to 10 times its outside diameter; in ВРГ (VRG) cable they should not be less than 6 to 8 outside diameters. Where the bends begin and end, fixing straps must be applied.

Preparatory Work. СРГ (SRG) and ВРГ (VRG) cables are secured with the same type of fixing straps as ТПРФ (TPRF) wiring; clips are also used. To fix the straps use is made of wire-spiral anchors, screws anchored with rolled p.v.c. tubing and plug dowels. When the cables are installed in damp and wet premises, wire-spiral anchors and clips are fixed with a cement mortar and not with plaster of Paris mortar.

The installation of these cables in through holes and where they are passed under obstacles is identical to that of ТПРФ (TPRF) wire (see Fig. 121).

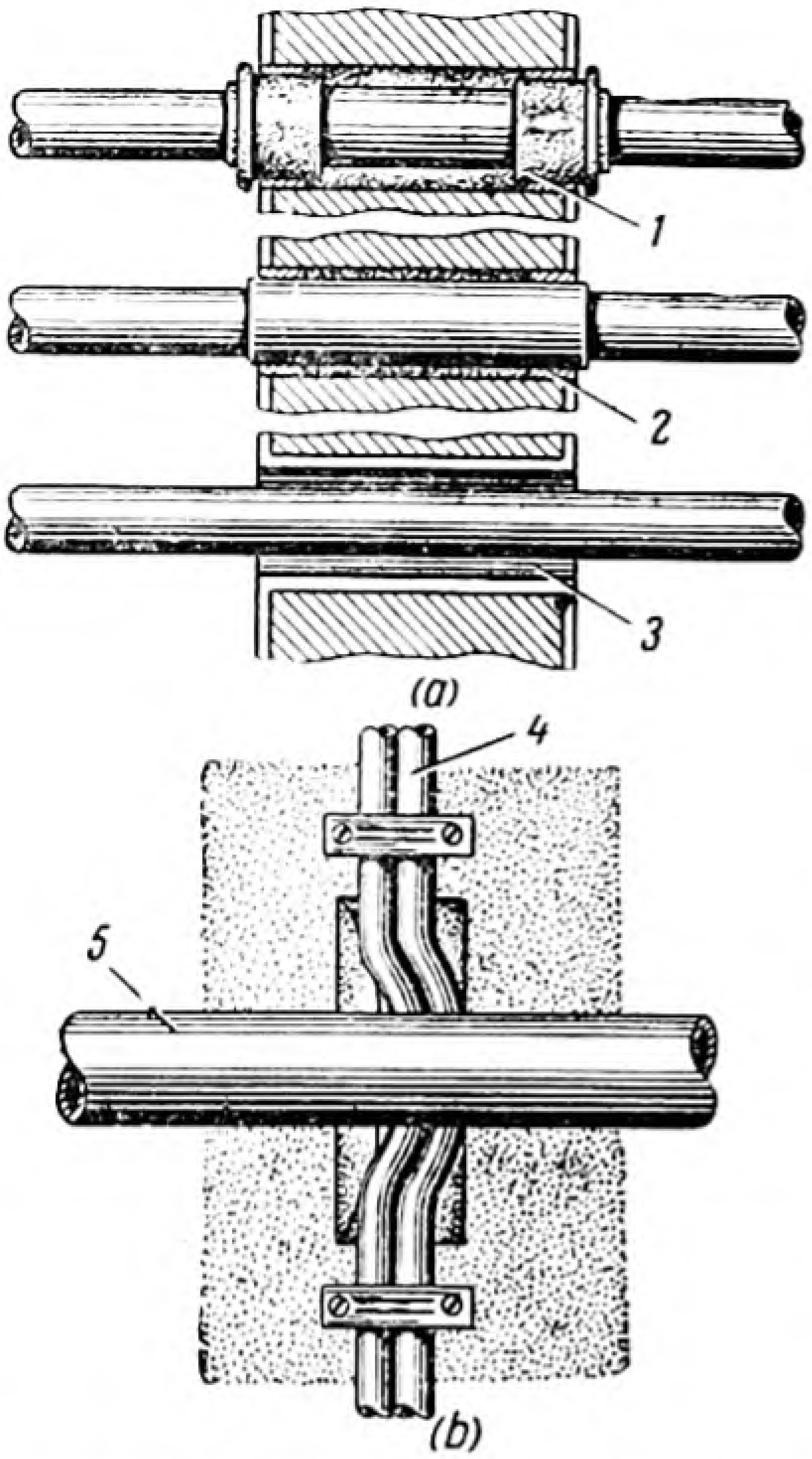


Fig. 121. Grade СРГ (SRG) and ВРГ (VRG) cable installation:
a—at through holes in walls, b—at obstacle in form of pipe; 1—semihard rubber tubing, 2—steel pipe, 3—plaster-surfaced hole, 4—cable, 5—intersecting pipe line.

These cables may be passed through holes in walls protected by semihard rubber tubing over the ends of which porcelain bushings are fitted.

Cable Installation. Immediately after these cables are reeled off their drums they are laid in the fixing straps and pulled through the holes in walls and under obstacles whenever such are met with.

The lengths of the cable are best measured off according to the marked-off lines of the runs. The cables can then be temporarily clamped by the straps or clips and brought up to the junction boxes. When СРГ (SRG) cable is installed, it is necessary to place flexible lining strips between the cable and fixing straps or clips, the strips being cut 4 to 5 mm wider than the straps or clips. These lining strips serve to protect the lead sheath from injury.

The connections and joints in the junction boxes of such wiring are made in the same way as with ТПРФ (TPRF) wire.

These cables must retain their hermetic tightness where they enter the junction boxes. For this, the junction boxes are made with sealing glands which reliably seal the entrance of the cable and protect it from ingress of moisture (Fig. 122).

After the cables have been connected and jointed in the junction boxes, they are smoothed out along their runs and finally secured with fixing straps or clips.

Mounting of Lighting Fittings, Lighting Switches and Plug Sockets. Lighting installations wired with СРГ (SRG) or ВРГ (VRG) cables are equipped with water-tight and dust-tight lighting units into which the cables are brought through entrance seals (Fig. 123).

When the lighting units require suspension further than 0.3 to 0.4 m, the cable is run down to them through tubular rods or along wire hanger rods.

The lighting switches, plug sockets and other devices of like nature are, as a rule, mounted on U-shaped stirrup brackets.

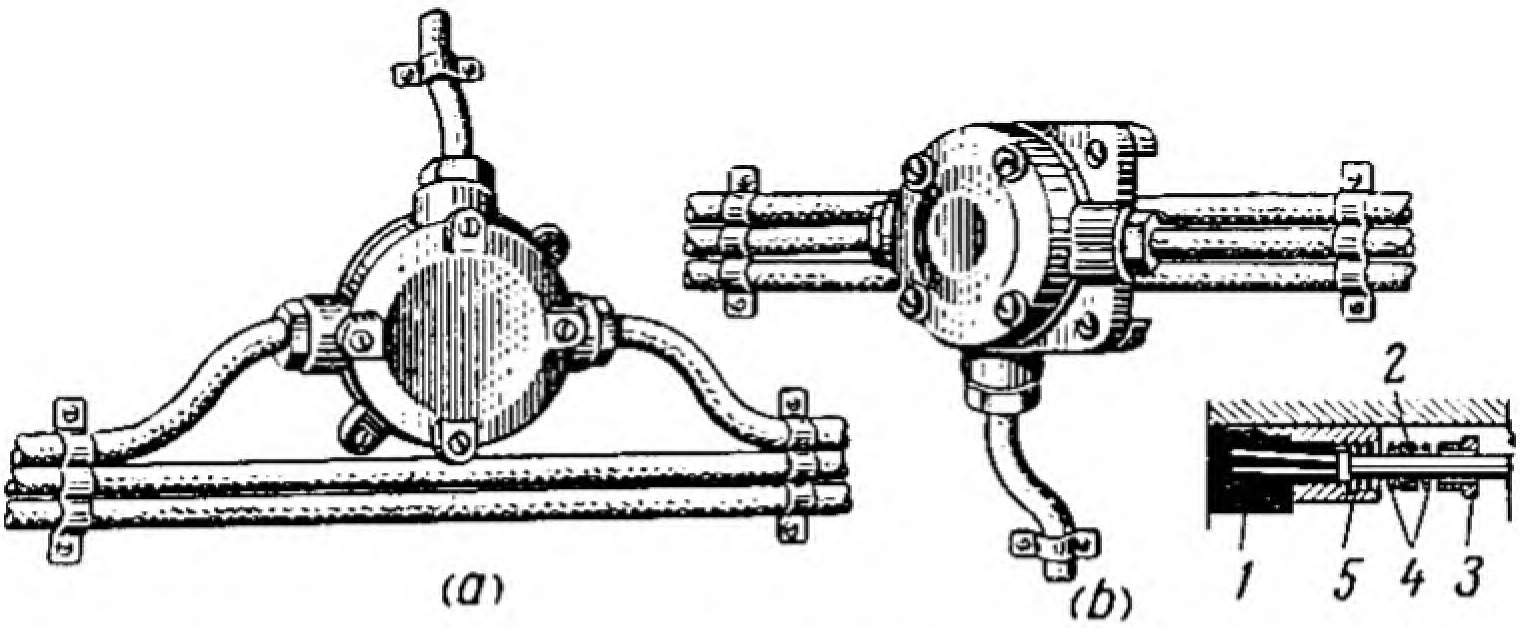


Fig. 122. Junction boxes used in installing grade СРГ (SRG) and ВРГ (VRG) cables:

a—boxes installed for tap-off, b—entrance of cable into box: 1—box, 2—rubber packing ring, 3—gland nut, 4—metal washers, 5—gland box.

The cables are brought into the above devices through the entrance seals with which they are provided (Fig. 124).

Task 1. Draw up an operation-sequence card for the dressing and termination of a size 3 × 2.5 sq mm ВРГ (VRG) p.v.c.-covered rubber-insulated cable.

Task 2. Draw up a bill of materials and list the tools and appliances required for installing a type РН-50 (RN-50) water- and dust-tight lighting unit to be hung from a concrete surface. Connect the tap-off cable to be run to the lighting unit to an existing circuit at an earlier installed junction box.

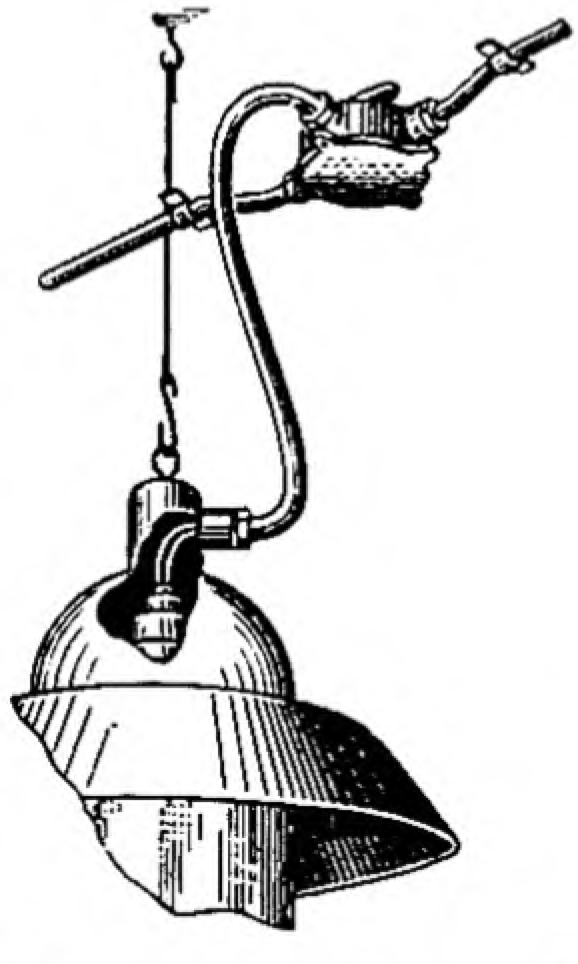


Fig. 123. Lead down of grade СРГ (SRG) and ВРГ (VRG) cables into a lighting unit.

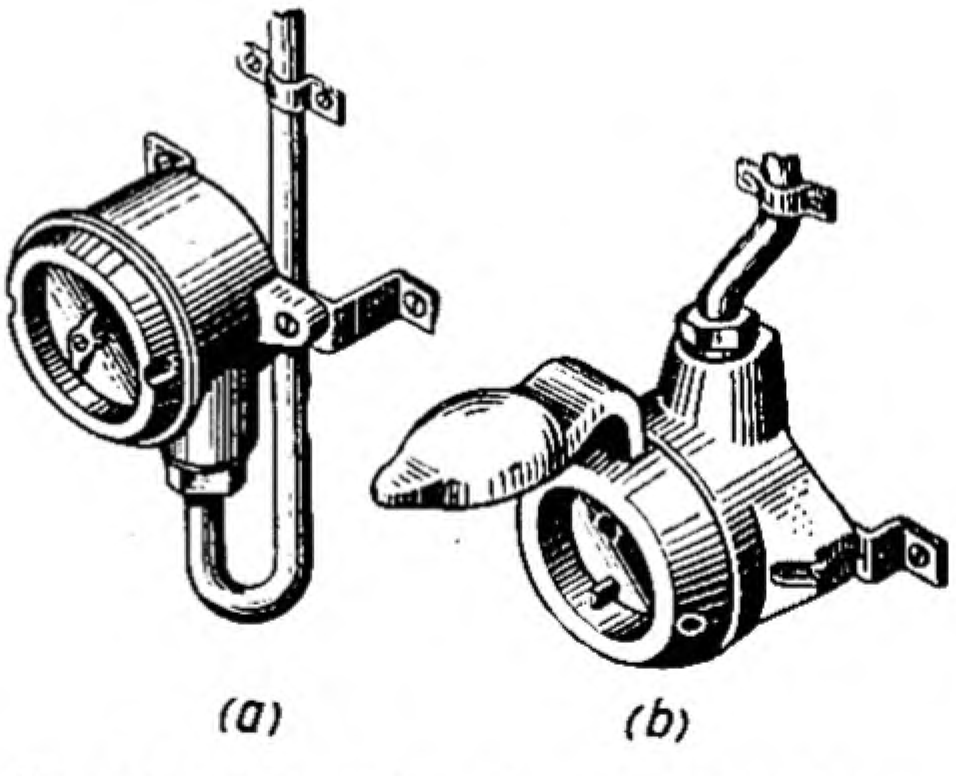


Fig. 124. Mounting of a switch and a plug receptacle in a circuit wired with grade СРГ (SRG) or ВРГ (VRG) cable:

a—cable brought into a switch, b—cable brought into a plug receptacle.

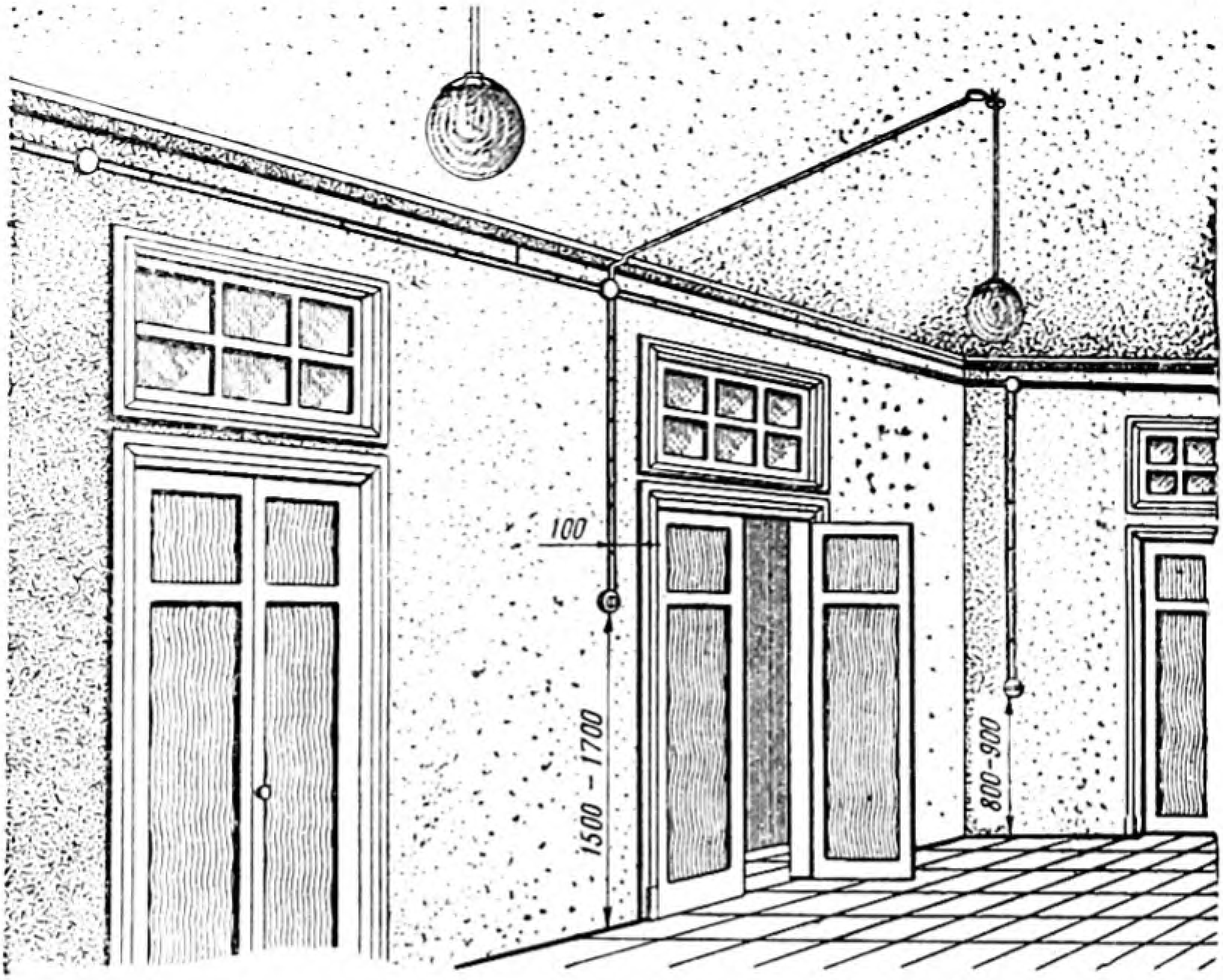


Fig. 125. General appearance of wiring installed with grade ППВ (PPV) flat p.v.c.-covered wire.

7. Surface Wiring with Grade ППВ (PPV) Flat P.V.C.-Covered Wire

Grade ППВ (PPV) flat p.v.c.-covered wire is used to install circuits in dry normal-atmosphere premises for voltages up to 380 volts.

For surface laying, grade ППВ (PPV) wire provided with a light-resistant p.v.c. covering is to be used.

Grade ППВ (PPV) wire is run directly fixed to the surfaces of walls, partitions and ceilings having a plaster or plasterboard finish. It is also directly fixed to papered walls and partitions of fire-proof construction.

As a rule, grade ППВ (PPV) wire must not be installed on unplastered wooden walls, partitions and ceilings. In unavoidable cases this grade of wire can be installed on unplastered wooden walls, partitions and ceilings by providing it with an underlying layer of sheet asbestos. Its width is such that 5 to 6 mm extend beyond each side of the wire.

Laying out and Marking off. Each run of grade ППВ (PPV) wire is laid out and marked off separately (Fig. 125), and the layout of the runs should follow the general architectural lines of the room to be wired.

During the laying out of such wiring, it should be borne in mind that a distance of 3 to 5 mm

must be left between wires which run parallel to each other. These wires should never be bunched or run so that they are in close touch with each other.

The point at which the wire is fixed shall, at through holes, be from 30 to 35 mm away from the centre of the hole, and, at junction boxes, 50 to 60 mm away from the centre of the box.

At turns in direction, grade ППВ (PPV) wire must have a radius equal to 5-6 times its width and be fixed at both sides of the turn.

On straight runs of wire the spacing of the fixing points should not exceed 150 to 200 mm (Fig. 126).

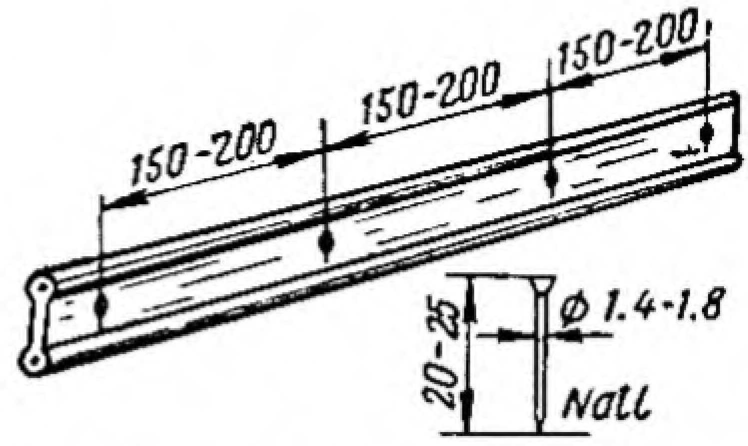


Fig. 126. Spacings for installing grade ППВ (PPV) wire.

Preparatory Work. To install grade ППВ (PPV) wire on plastered wooden surfaces, or on brickwork and concrete, it is fixed with nails 20 to 25 mm long having a head up to 3 mm in diameter.

When the wire is to be installed on unplastered brickwork or concrete surfaces, it is fixed with cemented-in clips (Fig. 127*a*) prepared from tin plate cut into 3 to 4 mm strips, 35 to 40 mm long. So that the clips may pierce the bridging film between conductors when laying the wire, their ends are cut to an angle of 45 degrees.

The holes for cementing-in the clips are driven with a triple-flute drift drill. The holes are made 20 to 25 mm deep and 8 to 10 mm in diameter. Cementing-in is done with plaster of Paris mortar.

A new method now gaining wide practice is that of directly

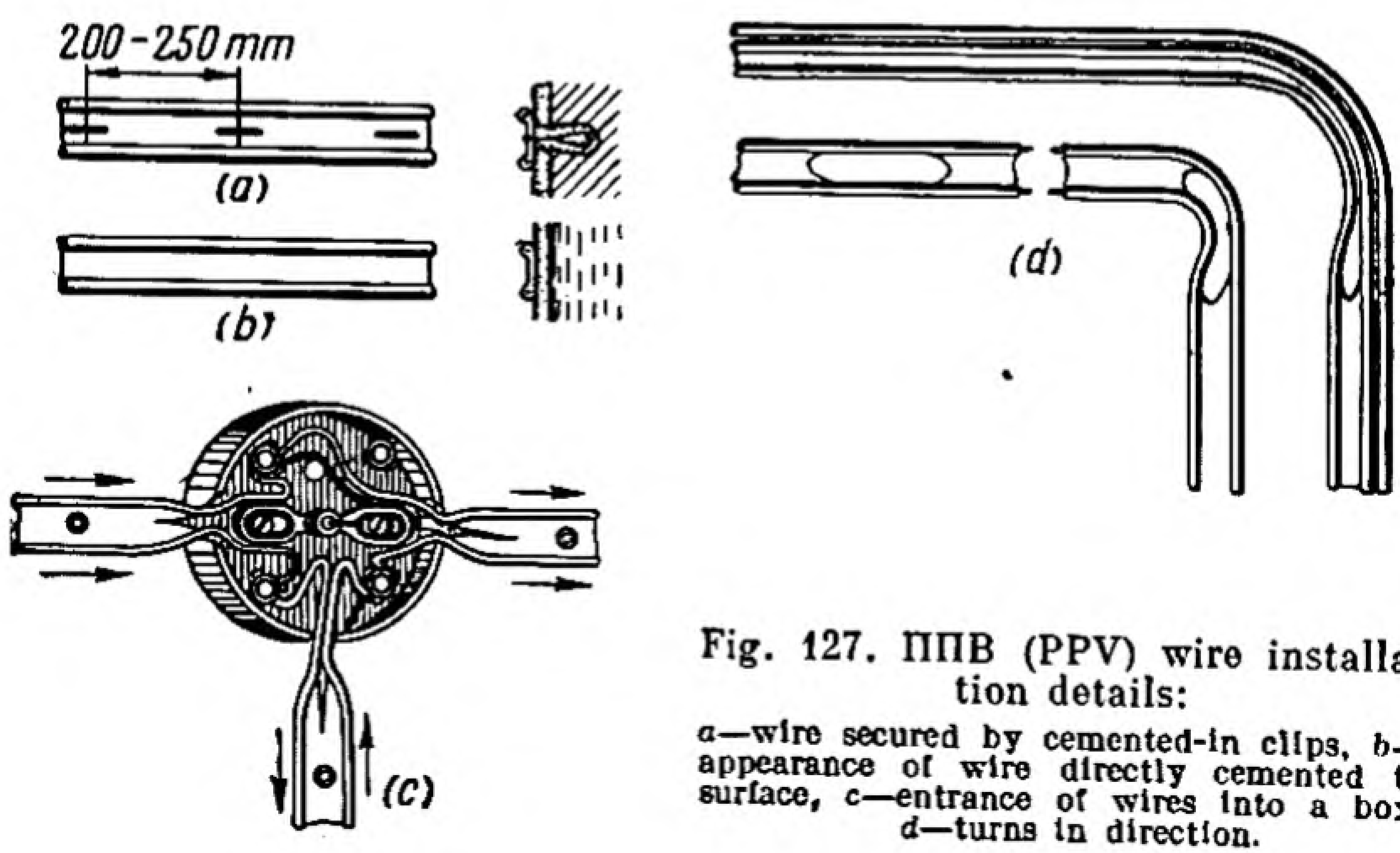


Fig. 127. ППВ (PPV) wire installation details:

a—wire secured by cemented-in clips, *b*—appearance of wire directly cemented to surface, *c*—entrance of wires into a box, *d*—turns in direction.

cementing grade ППВ (PPV) wire to support surfaces with a synthetic-resin adhesive (Fig. 127*b*).

In through-wall holes grade ППВ (PPV) wire must be protected by semihard rubber tubing, with insulating bushings fitted over the ends.

Where grade ППВ (PPV) wire is run through an overhead floor structure, it requires protection from mechanical injury and must be passed through in steel conduit pipe to a height of 2 m from the floor it pierces. To be passed under obstacles, grade ППВ (PPV) wire is laid in open plastered grooves.

Wire Installation. The first operations consist in unreeling the wire, smoothing it out by pulling it through a firmly held rag and measuring it off to length in accordance with the marked-off lines.

If the wire is secured with nails, the nails are started with a hammer and then driven home with blows on a handle-fitted striking pad (Fig. 128) serving to protect the conductors from injury by the broader hammer head.

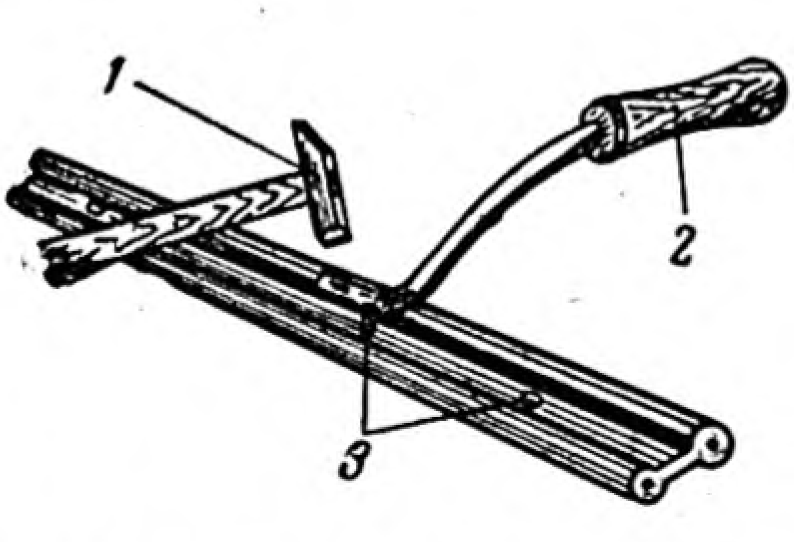


Fig. 128. Use of nail striking pad in installing grade ППВ (PPV) wire: *1*—hammer, *2*—striking pad tool, *3*—fixing nail.

When grade ППВ (PPV) wire is installed with clips, it is pierced by the ends of the clips in the middle of the bridging film in order to fix it by bending over the ends of the clips in opposite directions.

If the wire is to be installed by direct cementing to structural surfaces with synthetic-resin adhesive (with a composition of 25 per cent vinyl perchloride resin and 75 per cent ethylene dichloride), the adhesive is applied to the structural surface until it acquires the necessary stage of tackiness. After this, the wire is pressed over sections from 1.5 to 2 metres long against the surface and smoothed down with a rag.

As grade ППВ (PPV) wire is installed step by step, it is pulled through wall passages, laid in the grooves provided at obstacles and brought into the previously fixed junction boxes wherever it reaches them.

Where the wire enters a box, the bridging film is cut out. Within the box the conductors are either connected to the terminals (Fig. 127*c*) or jointed by the compression method.

The bridging film is also cut out where the wire makes a turn (Fig. 127*d*).

Mounting of Lighting Fittings, Lighting Switches and Plug Sockets. In circuits installed with grade ППВ (PPV) wire, many types of lighting fittings are used. They may be such as the opal-glass "Lutsetta" pendent fitting, a ball-shaped ceiling-mounted fitting, a dome-shaped

ceiling-mounted fittings or other type of fitting.

The wire run to a fitting suspended from the ceiling must be secured at 30 to 40 mm from the hook. The end of the wire must have the bridging film cut out over a distance of 50 to 60 mm and the conductors bared for connection to the internal hook-up wiring of the lighting fitting. The insulated joints are then tucked out of sight in the ceiling plate.

If the lighting fitting is to be mounted on a wooden rosette, the ППВ (PPV) wire is laid in the groove provided in the rosette and brought out at the centre where a hole 30 to 40 mm in diameter is made and within which the ППВ (PPV) and lighting fitting wires are jointed and hidden.

Lighting switches and plug sockets are mounted in the usual way. Before being brought in

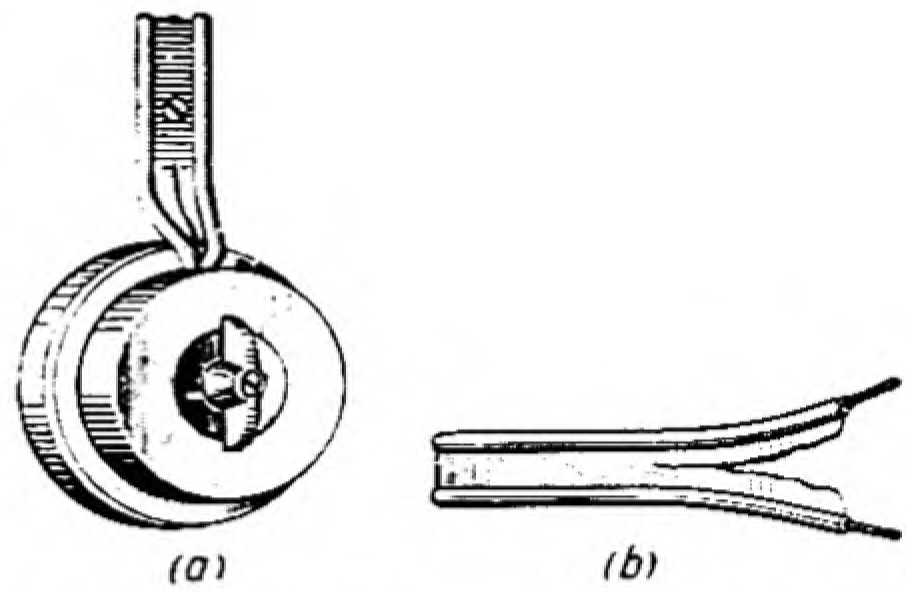


Fig. 129. Mounting a lighting switch when wiring with grade ППВ (PPV) wire:

a—connecting wire to switch, b—preliminary dressing of wire end.

to the switch or plug socket, the bridging film is cut out over a distance of 40 to 50 mm at the end of the wire (Fig. 129).

Example. Describe the sequence of operations to be followed in installing the circuit required by the floor plan given in Fig. 130 with grade ППВ (PPV) wire.

Solution. First lay out and

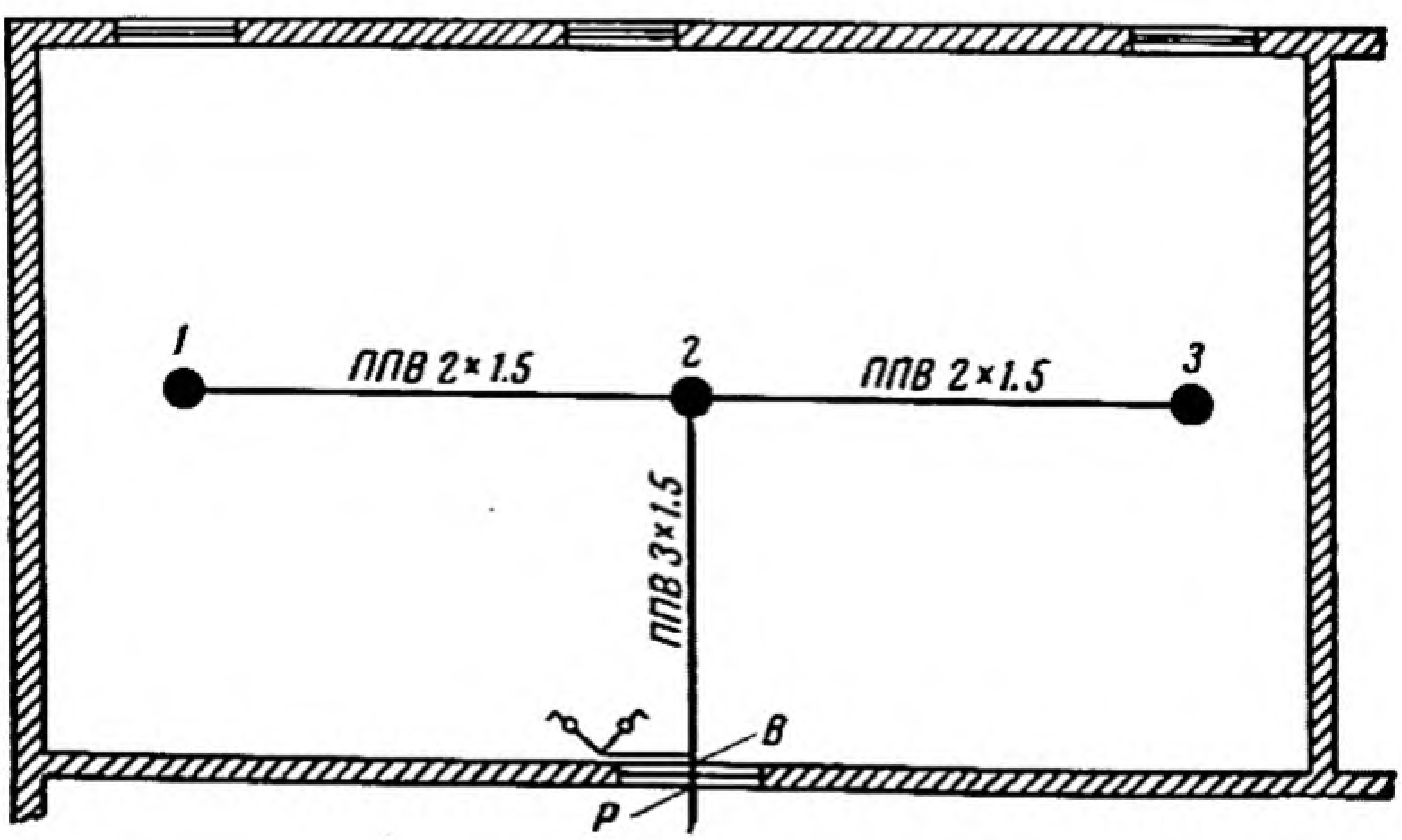


Fig. 130. Wiring floor plan:

1, 2 and 3—points of lighting fitting installation, P—passage through wall, B—location of junction box.

mark off the places for mounting the lighting fittings, lines of wiring and the run dropped to the switches.

Next, drill with a gimlet through hole at passage point *P* and fit it with 11-mm diameter semihard rubber tubing having a length equal to the thickness of the wall, plus 5 mm for entrance to the junction box and 5 mm allowed for the rims of the bushings. At the outside end of the hole cement in a bushing after slipping it over the end of the tubing.

Run the end of the ППВ (PPV) wire through the tubing (the length of this wire is equal to the length of the passage hole, plus 75-80 mm allowed for entering the junction box and making connections with other wires, and also plus the length required for connecting the wire to the branch feeder). At the same time mount the junction box and lead in the end of the wire through its bottom.

Now install the 2×1.5 sq mm ППВ (PPV) wire from the mounting point of lighting fitting *1* up to lighting fitting *3*, running it through the mounting point of lighting fitting *2* where a loop must be left for making connections and setting up the necessary circuit arrangements.

Install the 3×1.5 sq mm ППВ (PPV) wire from the position of lighting fitting *2* up to junction box *B*.

After this, run a length of 3×1.5 sq mm ППВ (PPV) wire from box *B* down to the lighting switches.

Mount the lighting fittings and connect them to the wiring. Cut the loop at lighting fitting *2*, bare the conductors and joint them according to the required circuit arrangement. Insulate the completed joints and tuck them behind the ceiling plate of the lighting fitting.

Connect the ends of the wires in junction box *B*.

Mount the lighting switches and connect the ends of the wires to them.

Task. Draw up according to the form shown earlier an operation-sequence card for the job of installing a branch run to be tapped off from a two-conductor circuit of ППВ (PPV) wire to supply a plug socket.

Include in the card the operations of mounting the junction box, lead-in of the wires to it, termination of the ends of the wires and the making of their connections. The box must be mounted on a concrete surface.

8. *Steel-Pipe Conduit Wiring*

Wiring is installed in steel pipes to isolate it from the surrounding medium, for example, in explosion-hazardous premises (by air-tight piping), or reliably protect it from mechanical injury (for instance, where wiring is run under floors, at accessible heights, etc.).

The highest voltage for which such wiring can be installed is 500 volts.

A general view of steel pipe conduit wiring is shown in Fig. 131.

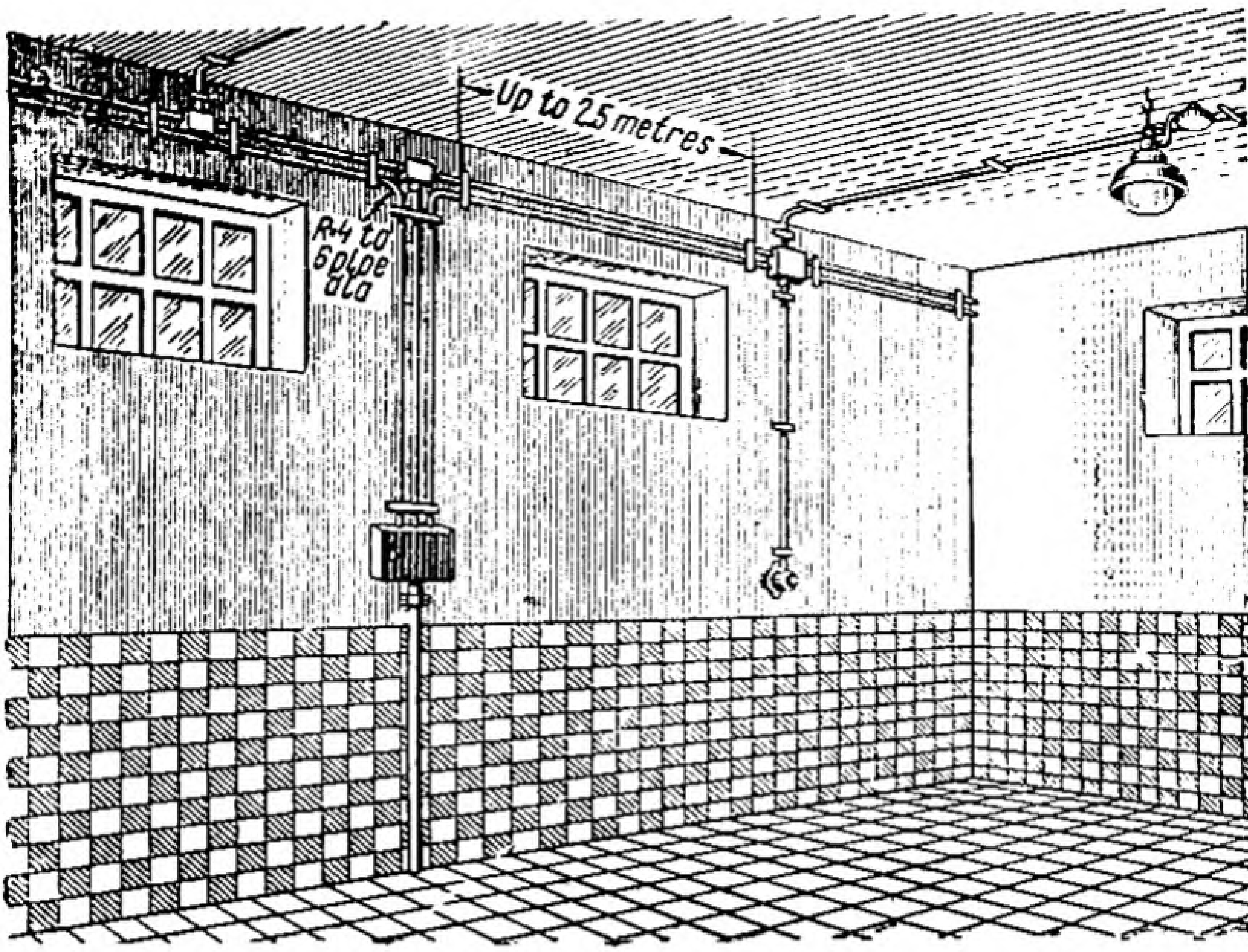


Fig. 131. General appearance of a pipe conduit installation.

Preparation of Steel Pipes. The most rational way of preparing steel pipes for electric wiring is to carry out this work in central installer's shops having special processing lines equipped with cutting off, pipe threading and counterboring machines and with pipe benders (hand- and power-operated).

Before any machining can be done on the pipes, they must be cleaned and coated with paint on special installations (Figs 132, 133, 134).

After receiving a coating of paint, the pipes are dried in a special dry room and then returned to the processing line for machining (Fig. 135).

The operations performed in preparing the pipes on the processing line are the following:

Preparation of straight lengths of pipe up to 2 1/2" in size. The

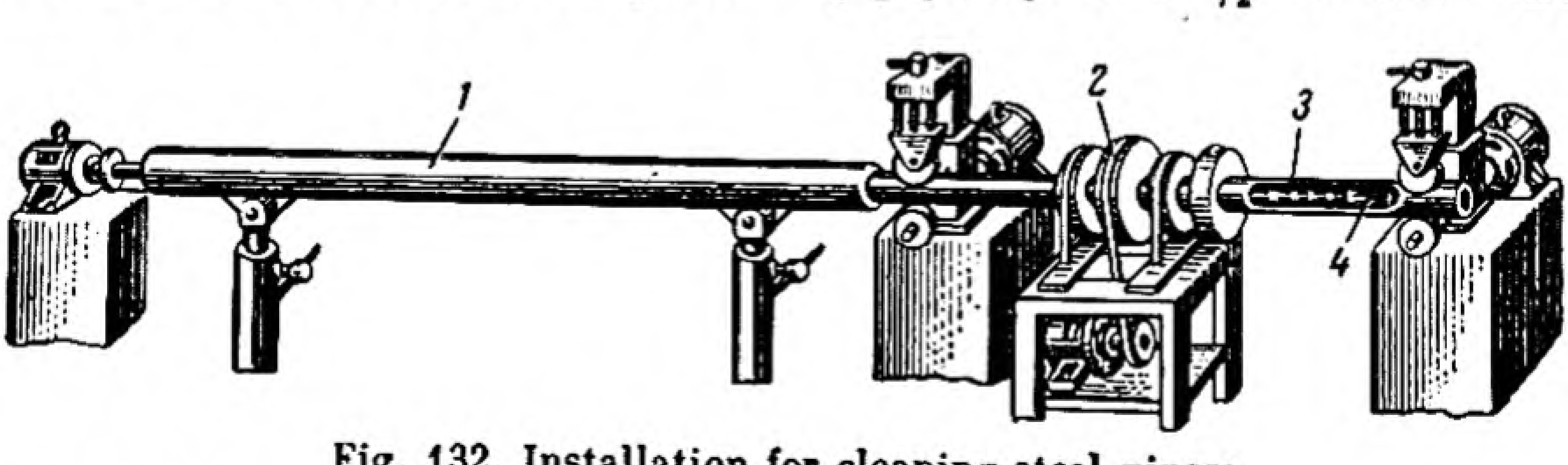


Fig. 132. Installation for cleaning steel pipes:
1—guard tube, 2—external surface cleaning unit, 3—brushes used to clean internal surfaces, 4—counterbore used to remove burrs from inside surface of pipes.

pipes are run over roller *1* on to gathering bench *2* where they are measured off to required length with the steel rule fixed to the bench. The measured pipes are passed over the rollers secured to the side of gathering bench *2* to cutting-off machine *3* from which, after cutting, they are piled on gathering bench *4*. From gathering bench *4* the cut pipes are rolled down inclined angle-iron rails *5* to machines *6* and *7* for counterboring.

The installation on which the ends of the pipes are counterbored is shown in Fig. 136.

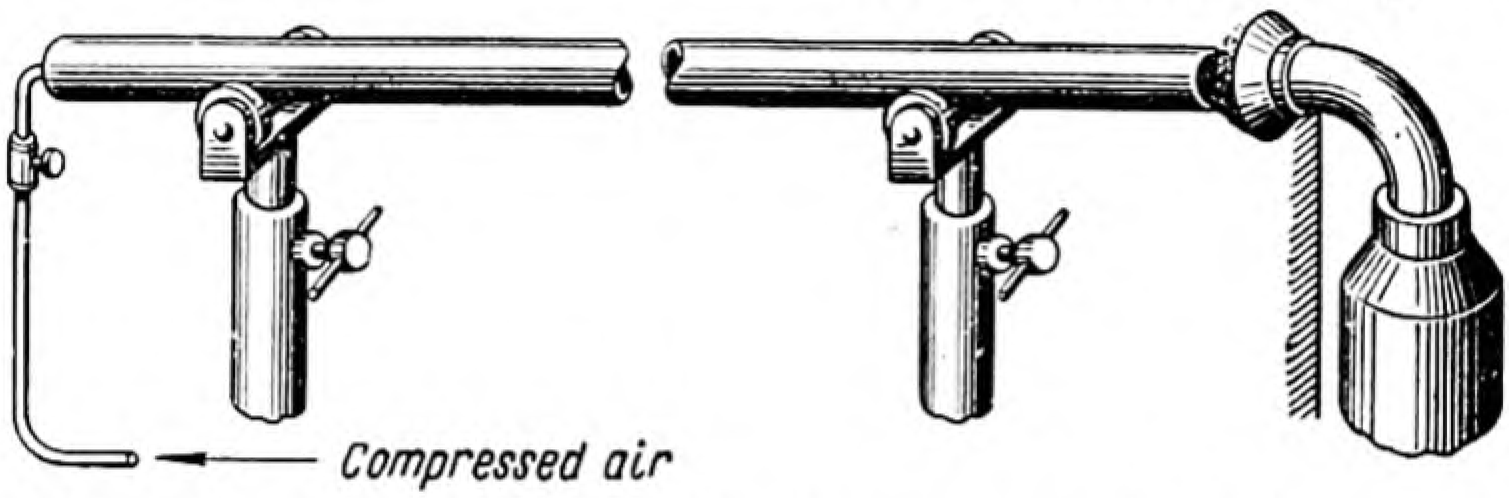


Fig. 133. Arrangement used for blowing out steel pipes after cleaning.

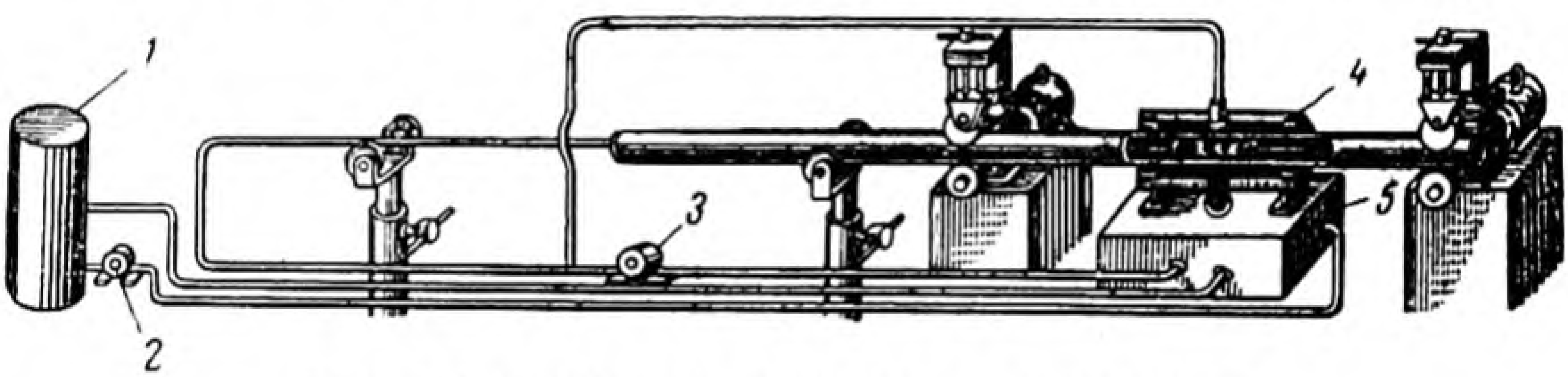


Fig. 134. Steel pipe paint coating installation:
1—electric heating unit, *2*—water circulating pump, *3*—varnish or paint delivery pump, *4*—chamber for coating external pipe surfaces, *5*—varnish or paint tank.

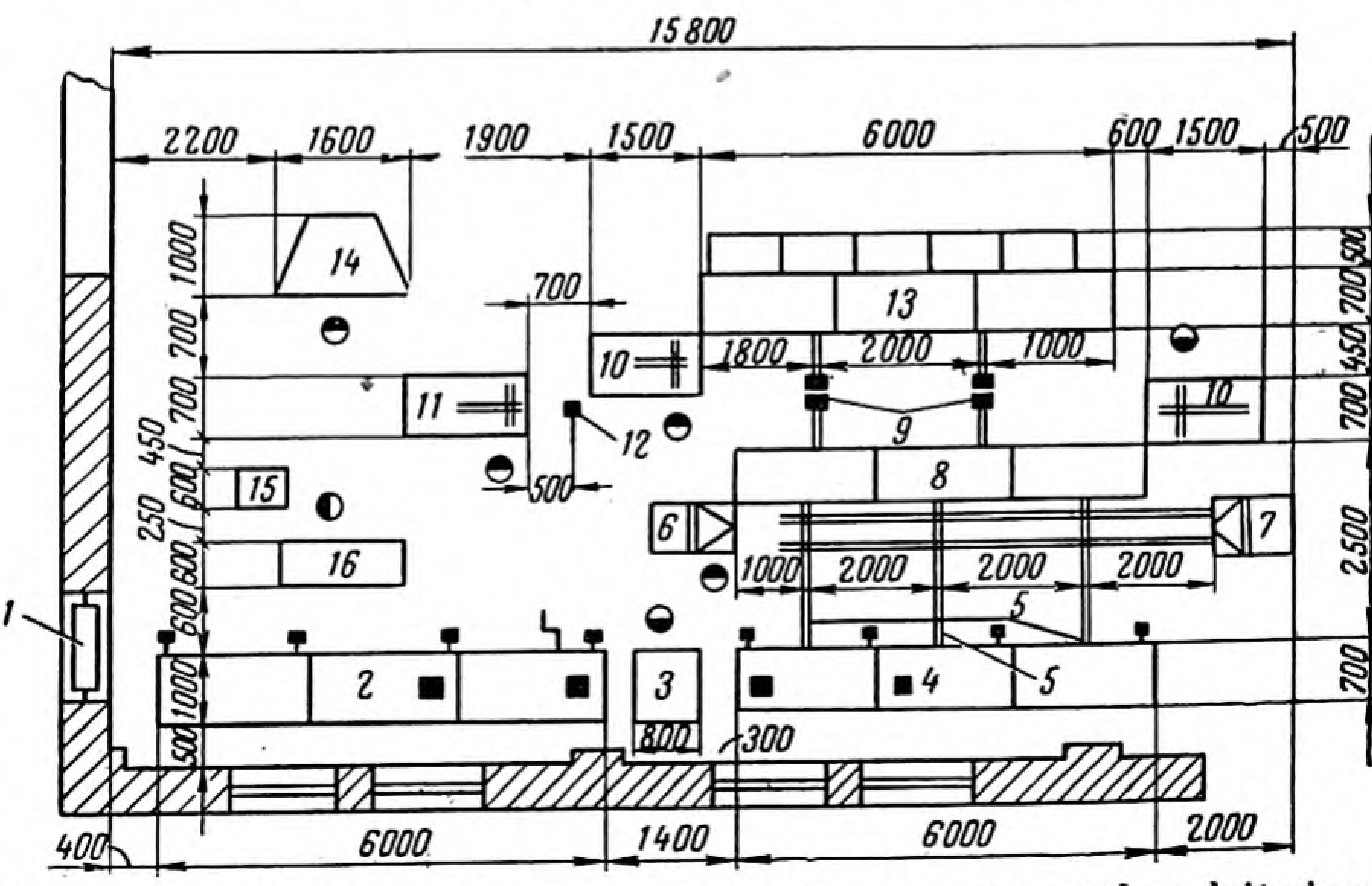


Fig. 135. Layout of production line equipment for processing steel conduit pipes.

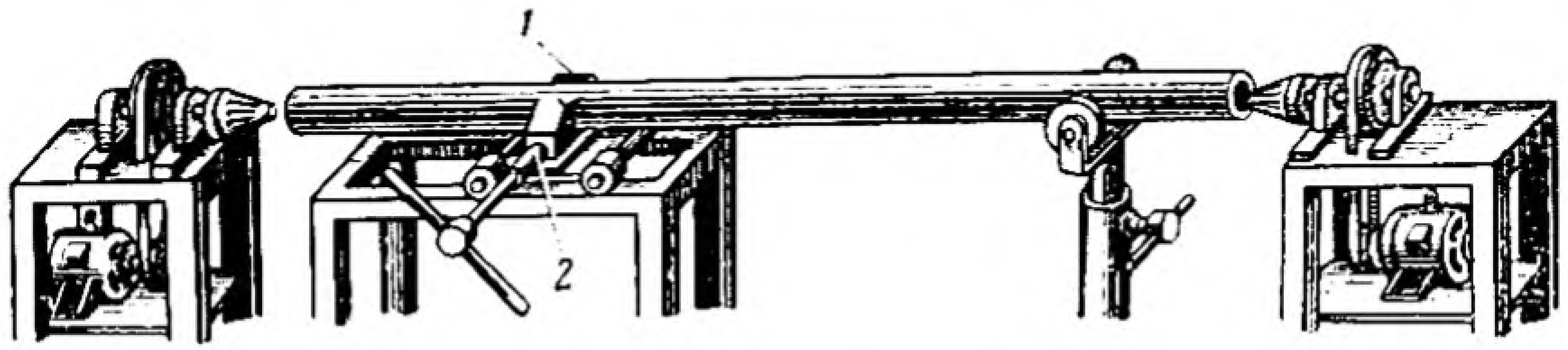


Fig. 136. Installation for counterboring ends of steel pipes:
1—self-centring vise, 2—pipe-travelling carriage.

After counterboring, the pipes are placed on gathering bench *8* (Fig. 135) from which they are passed to machines *10* where they are threaded and then piled on gathering bench *13*. From the latter the pipes are routed to the ready-pipe storeroom.

Preparation of straight lengths of pipe 3" and 4" in size. These sizes of pipes undergo the same operations as those stated above, the counterboring operation included. After counterboring, the pipe blanks are routed to machine *11* for threading. From thread-cutting machine *11* they are passed to gathering bench *13* and then taken to the ready-pipe storeroom.

Preparation of full-length pipes. Full-length pipes requiring no threading are routed over the rollers of gathering benches *2* and *4* and down inclined angle-iron rails *5* to the counterboring machines. After counterboring, the pipes are grouped on gathering bench *8* and then taken to the ready-pipe storeroom.

Standard bent-elbow production. The pipes to be made up into standard bent elbows, until they arrive on gathering bench *13* as ready-length blanks for bending, undergo the same operations as straight length pipes. From gathering bench *13* the $^1/_2$" and $^3/_4$" size elbow blanks are passed to hand-operated pipe-bender *15*, and all elbow blanks of 1" pipe size and greater are routed to motor-driven pipe-bender *14*.

Posts *9* and *12* serve for transfer and support of the pipes. For subsequent routing to the storeroom the ready bent elbows are piled on bench *16*.

The dimensions of standard bent pipe elbows $^1/_2$" and $^3/_4$" in size are shown in Fig. 137. Fig. 138 shows the dimensions for 1" to 3" elbows.

Figs 139, 140 and 141 illustrate how the operators work on cutting-off, pipe-threading and pipe-bending machines.

The degree of bending is controlled by comparison with templates or gauges prepared beforehand from 4 to 6 mm wire.

Steel-Pipe Conduit Installation. Full-length (6-metre) pipes should have short-length (standard) thread on both ends and a coupling screwed over one end.

Short, straight pipes should have a short-length thread at one end and at the other end a running thread over which are screwed a coupling and a lock nut.

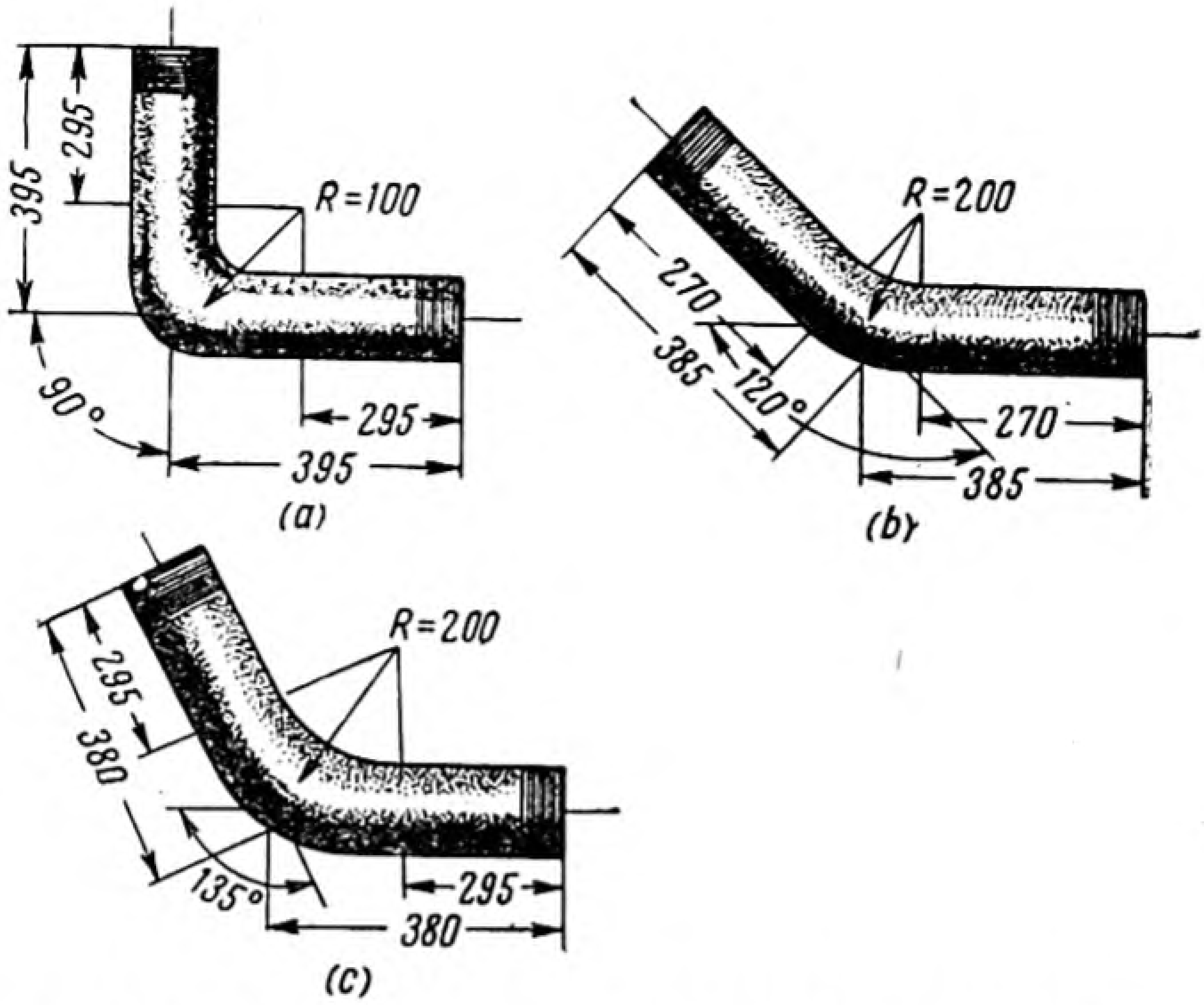


Fig. 137. Standard bent elbows for $^1/_2''$ and $^3/_4''$ pipes:
a—90° elbow, length of blank 780 mm; b—135° elbow, length of blank 750 mm; c—120° elbow, length of blank 750 mm.

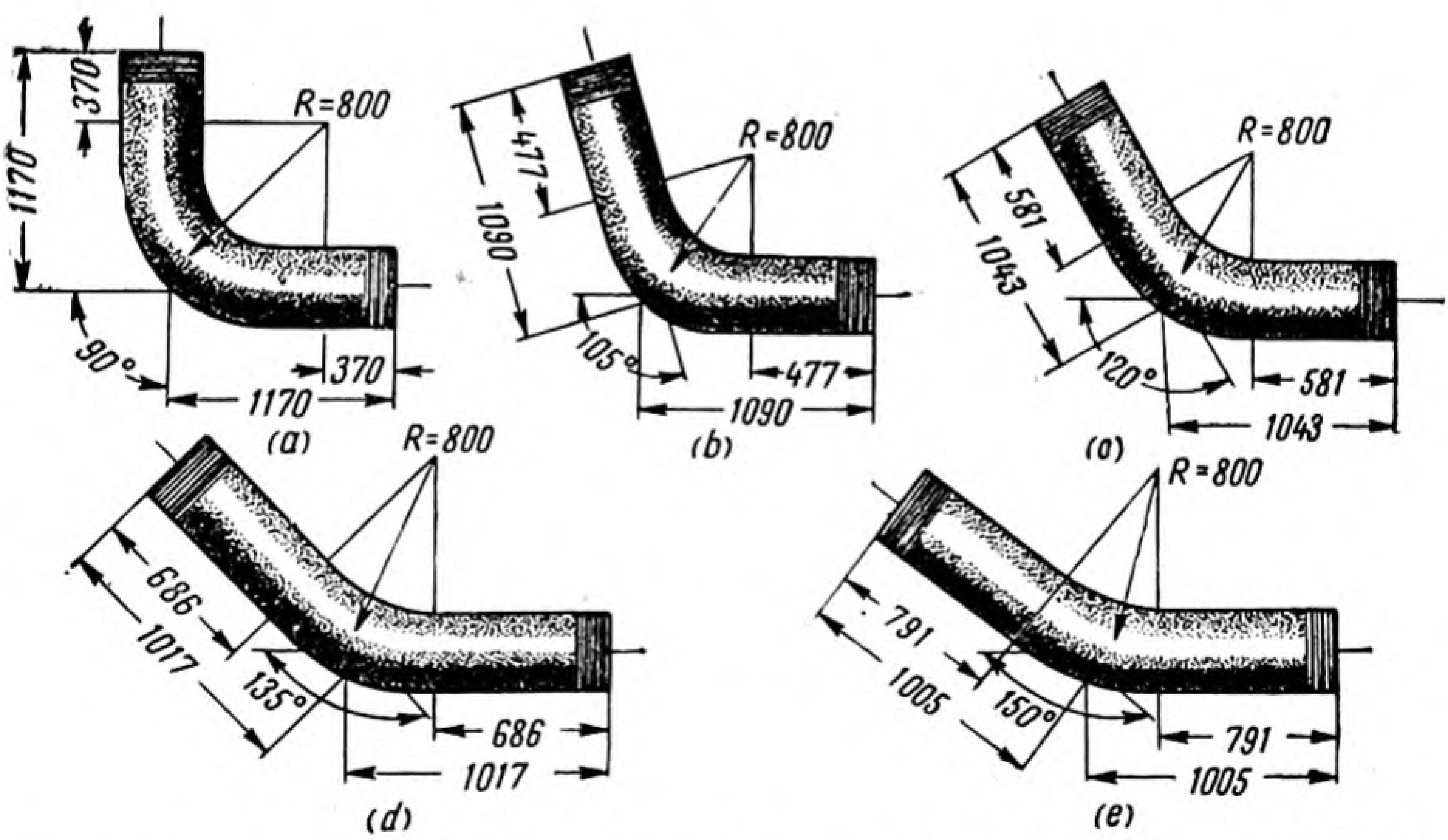


Fig. 138. Standard bent elbows for pipes of 1" to 3" diameter, length of blanks up to 2,350 mm:
a—90° elbow, b—105° elbow, c—120° elbow, d—135° elbow, e—150° elbow.

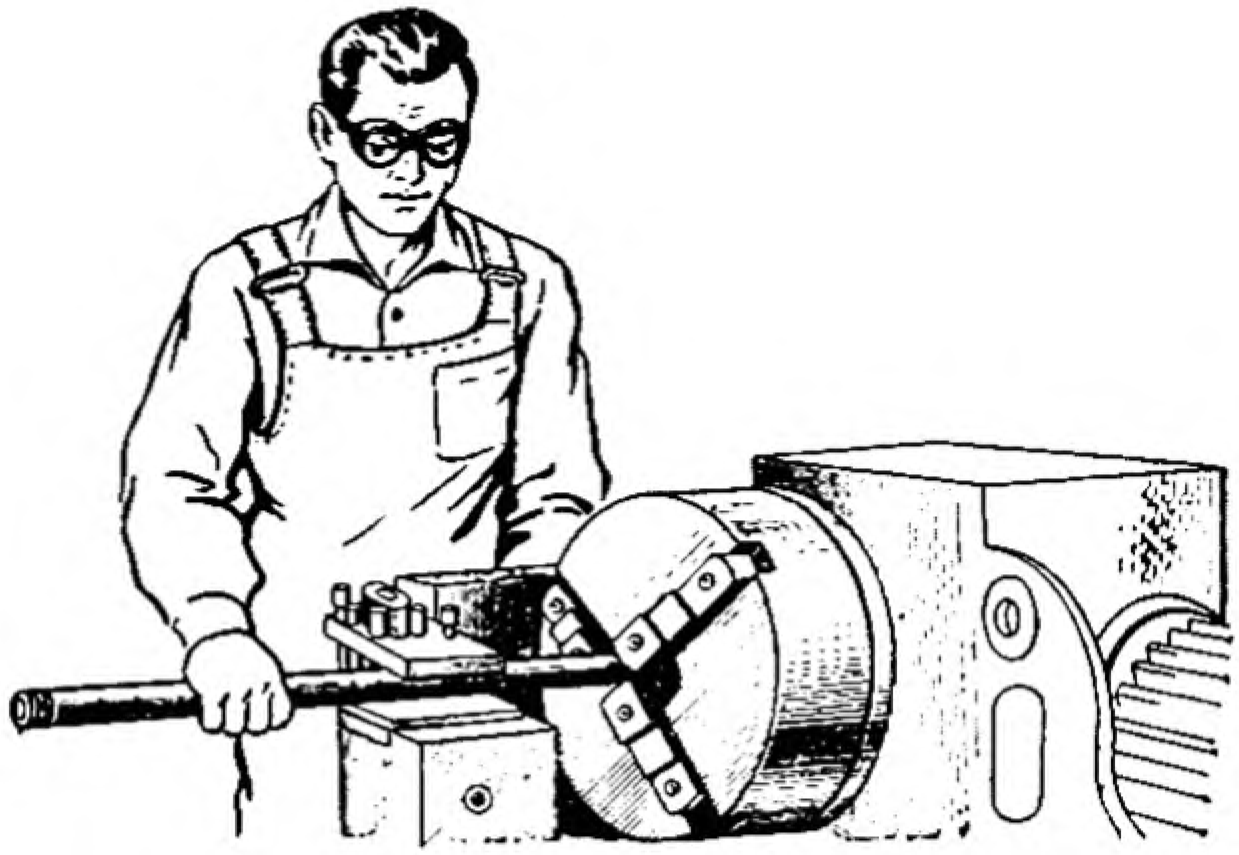


Fig. 139. Cutting pipes to length on cutting-off machine.

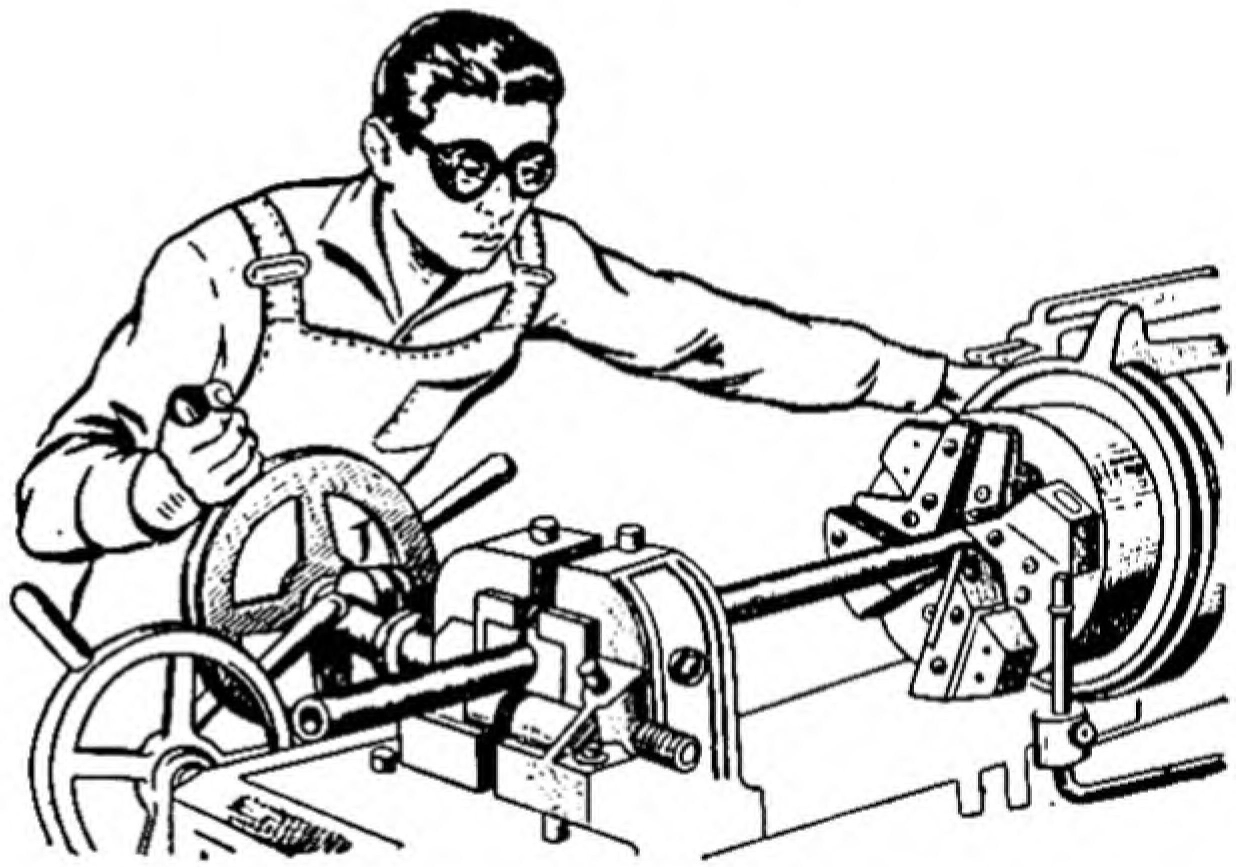


Fig. 140. Threading of pipe on pipe-threading machine.

Fig. 141. Pipe being bent on pipe-bending machine.

The ends of standard bent elbows should be running-threaded and have a coupling and a lock nut screwed on one end.

All pipe parts, the full-length pipes included, must be sent to the installation sites paint coated on the inside and counterbored at both ends.

Support metalwork for installing conduit piping can be prepared on site or in central workshops. The spacings observed in supporting conduit piping in sizes up to $1^1/_2$" range from 2.5 to 3 m; a spacing of 3.5 m between supports is used for pipe sizes over $1^1/_2$".

Separate conduit pipes may be directly fixed to walls and ceilings by straps of strip steel. Stirrups made from perforated metal or angle iron and bracket constructions are also used to install conduit piping, the fixing in these cases often taking the form of round-steel clips or straps (Figs 142, 143).

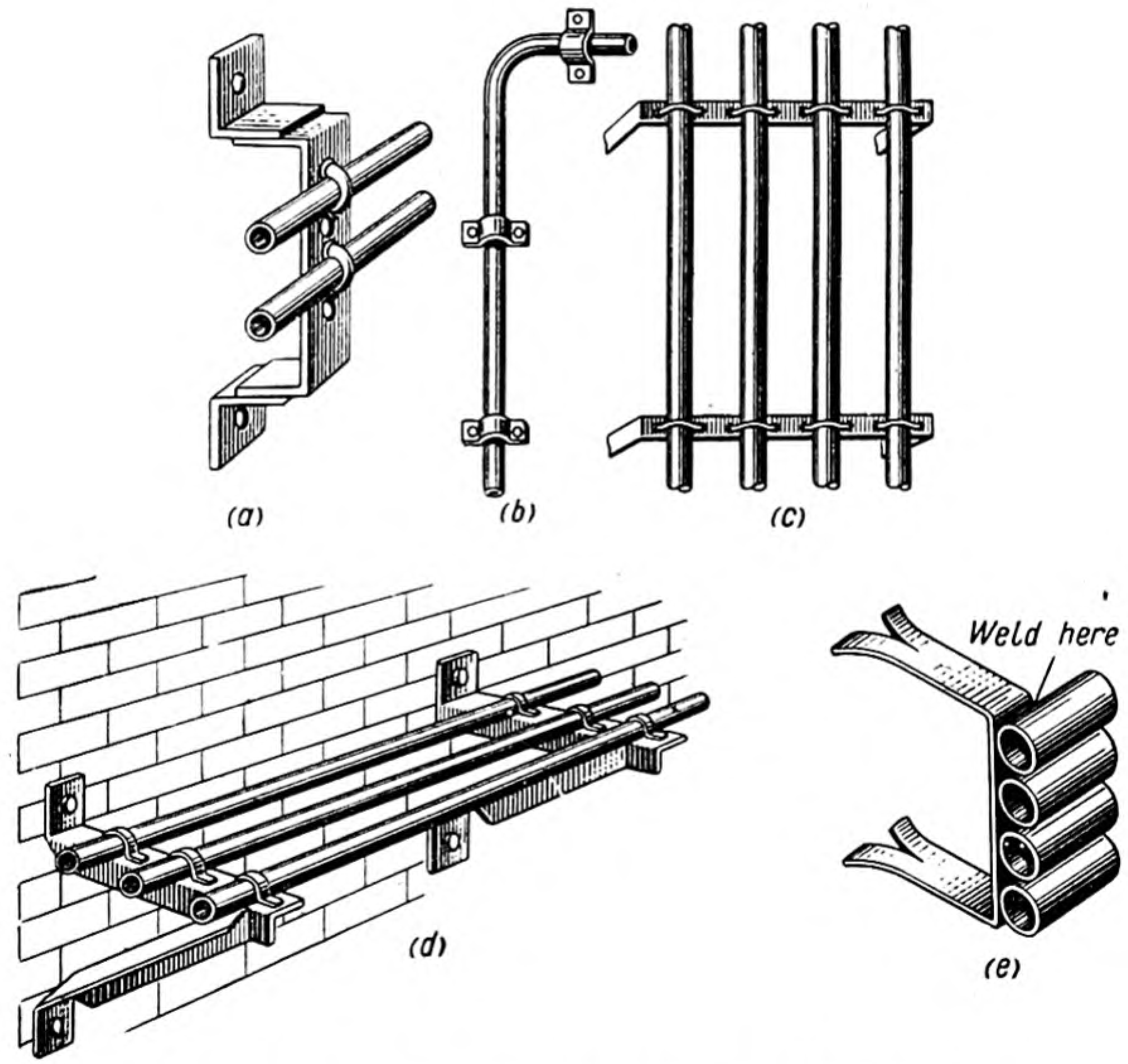


Fig. 142. Various ways of fixing steel pipe conduit:
a—with round steel clips and perforated steel strip stirrups, b—with steel strip pipe straps, c—with round steel clips on angle iron stirrups, d—on brackets, e—fixing by welding to support metalwork.

Widely practised is the method of arc-welding pipe conduits to their fixing supports.

Relatively short lines of conduit piping (up to 10 to 15 m long) are installed by putting in the pipes starting from one end and finishing at the other. When conduit runs are of considerable length, it is considered best to put in the piping by starting from both ends and proceeding towards the centre to a section such as *A* in Fig. 144.

Conduit pipe is jointed with pipe couplings. For this, the end of one of the pipes is provided with a short-length or standard thread and the end of the other pipe is provided with a running thread (for making a running-thread joint, Fig. 145). The joints are sealed with a wrapping of tow impregnated with red lead mixed in boiled linseed oil wound over the short thread and the coupling screwed over it from the running-thread side.

At the running-thread side the joint between the coupling and the lock nut is sealed by winding impregnated tow twisted into yarn between them before the lock nut is tightened.

As soon as each section of conduit pipe is joined to the one which has just been installed, it is fixed to its supports.

In a case such as shown in Fig. 144, the length of the middle section *A* is measured off to fit the distance left between the last pipes to be jointed.

Section *A* is usually cut and threaded on site, but, when a

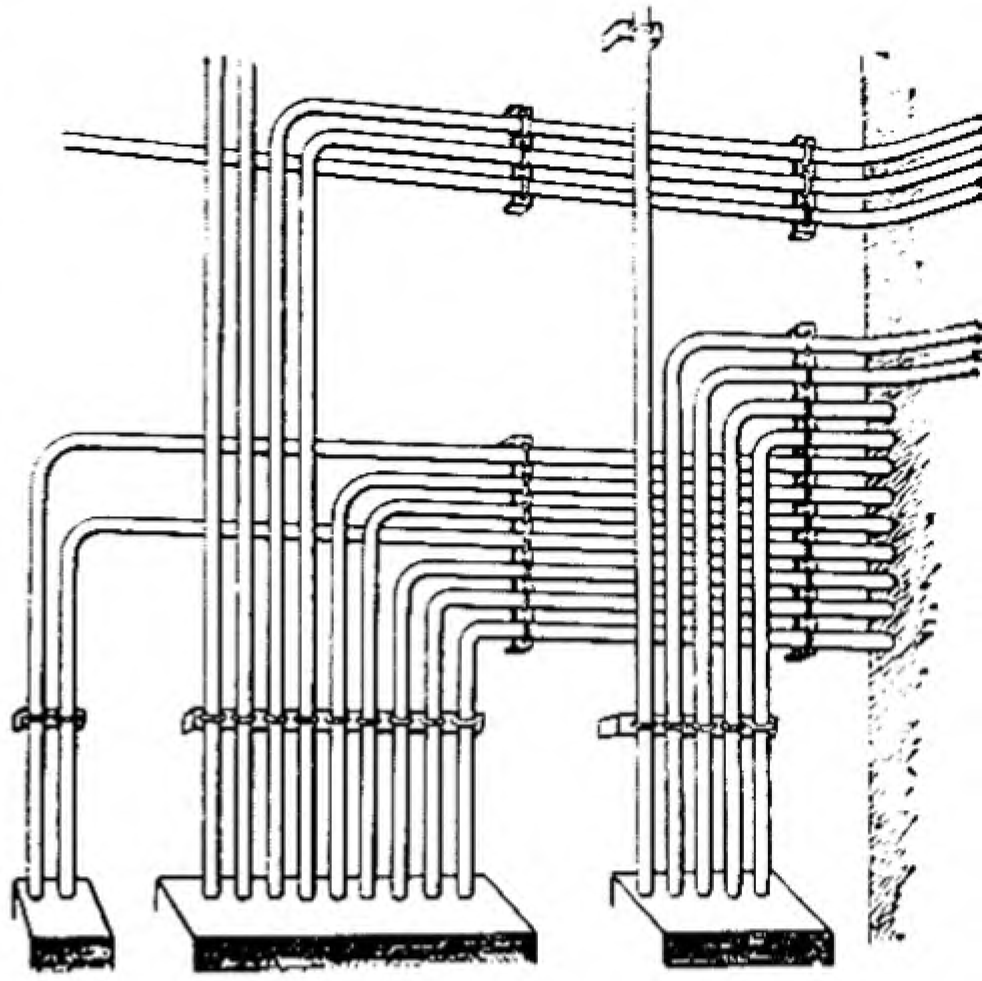


Fig. 143. Complicated section in a conduit installation.

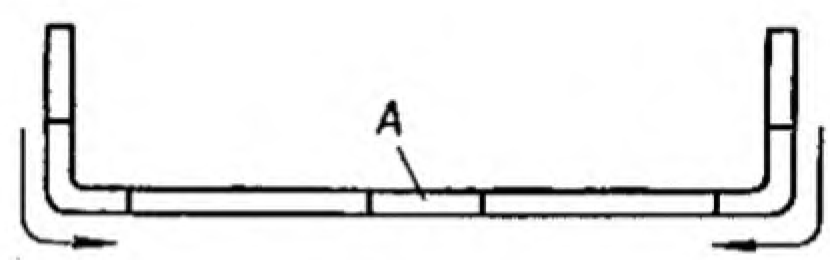


Fig. 144. Diagram showing directions of assembly of long conduit piping runs.

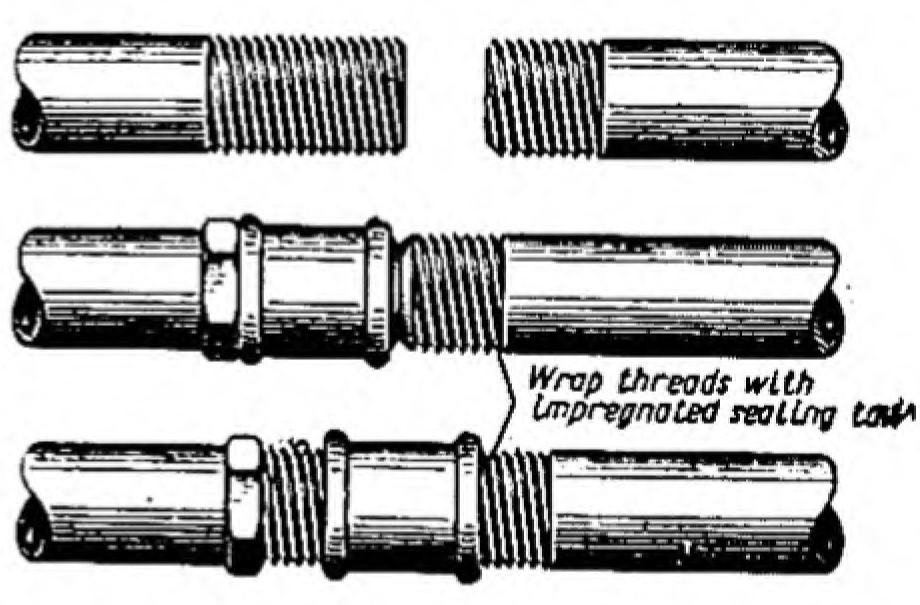


Fig. 145. Running thread and coupling jointing of steel pipes in air-tight installations.

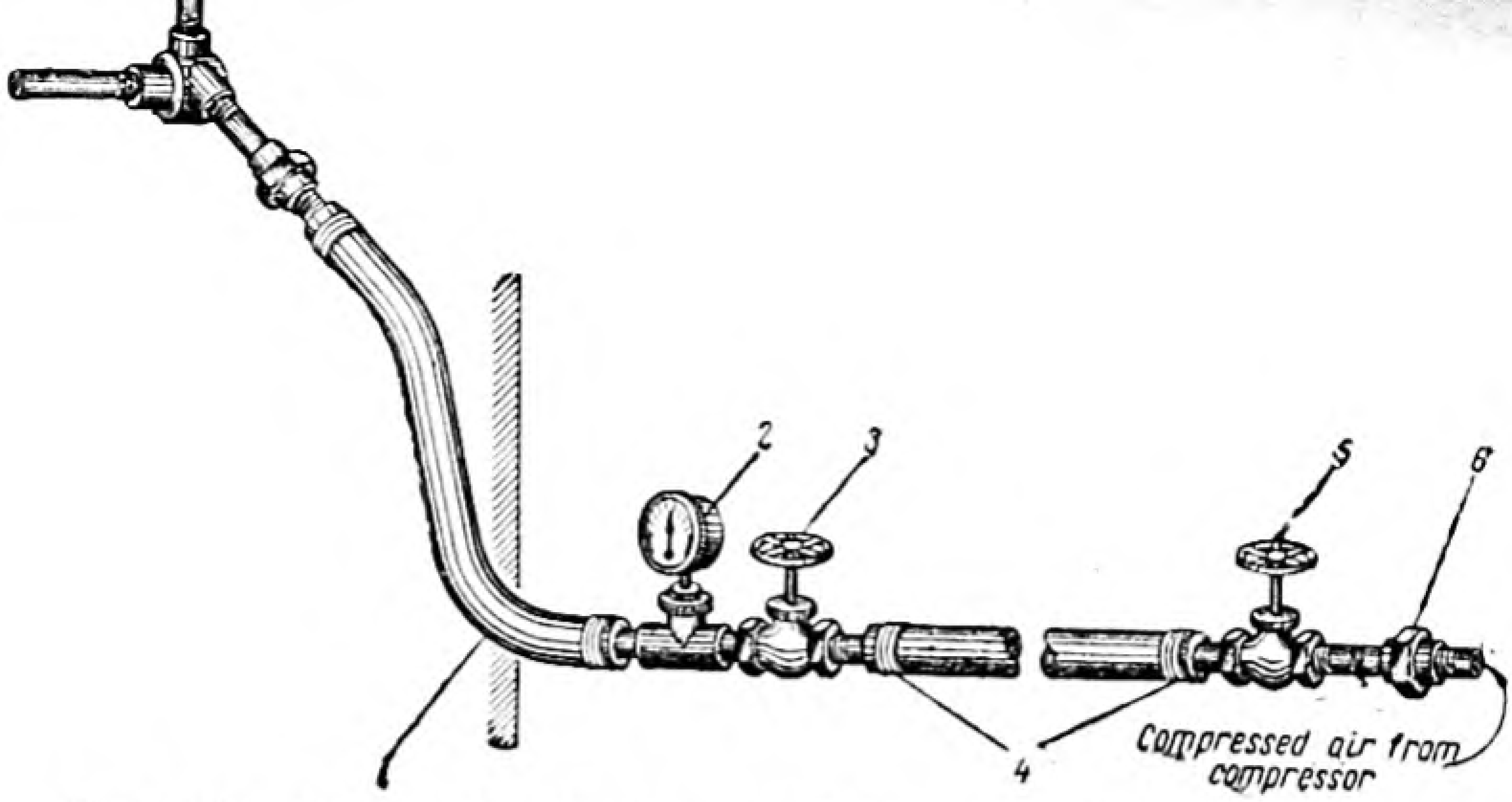


Fig. 146. Set-up for testing conduit piping for air-tightness:
1—high-pressure hose (oxy-acetylene welding hose), 2—pressure gauge, 3—pressure-discharge valve, 4—wire bandings, 5—stop valve, 6—pipe union.

large number of runs of conduit consisting of sections of the same size must be installed, such sections may be prepared in central workshops.

The short-threaded end of section *A* pipe is usually jointed to the pipe installed prior to it by the coupling preliminarily screwed on the end of the latter. The other end of section *A* pipe having the running thread is jointed to the piping by screwing the coupling on its thread on to the end of the pipe opposite it and completing the running-thread joint.

After the section *A* length of pipe has been jointed to its neighbours, the latter are fixed to their support metalwork.

The jointing and junction boxes used in such wiring are installed in the process of installing the conduit piping.

Conduit piping installed in explosion-hazardous shops and premises requires testing with compressed air for air-tightness (Fig. 146).

When the installation of conduit piping has been completed, the external surfaces of the pipes are given a second finish coating of paint.

Today special thin-wall steel tubes are widely used for installing wiring (Fig. 147). Such tubes are installed in the same way as ordinary steel pipes. To make bends in them, thin-wall pipe-benders are employed (Fig. 148). For bending a tube, the pipe-bender is set in the position shown in the upper part of Fig. 148 and the tube is slid into one of the grooves in the guide plate (depending upon its diameter) and then secured by the clamp to the wheel-like bending mandrel. As bending of the tube takes place, the guide plate is kept pressed against the stop and the roller to protect the tube from being crushed.

Wire Installation. Wires are drawn or pulled into pipe and thin-wall tube conduit from box to box by means of a steel fishing wire first pulled in with a flexible snake line.

The snake line is of coil construction and has the form of a wire spiral wound so that the

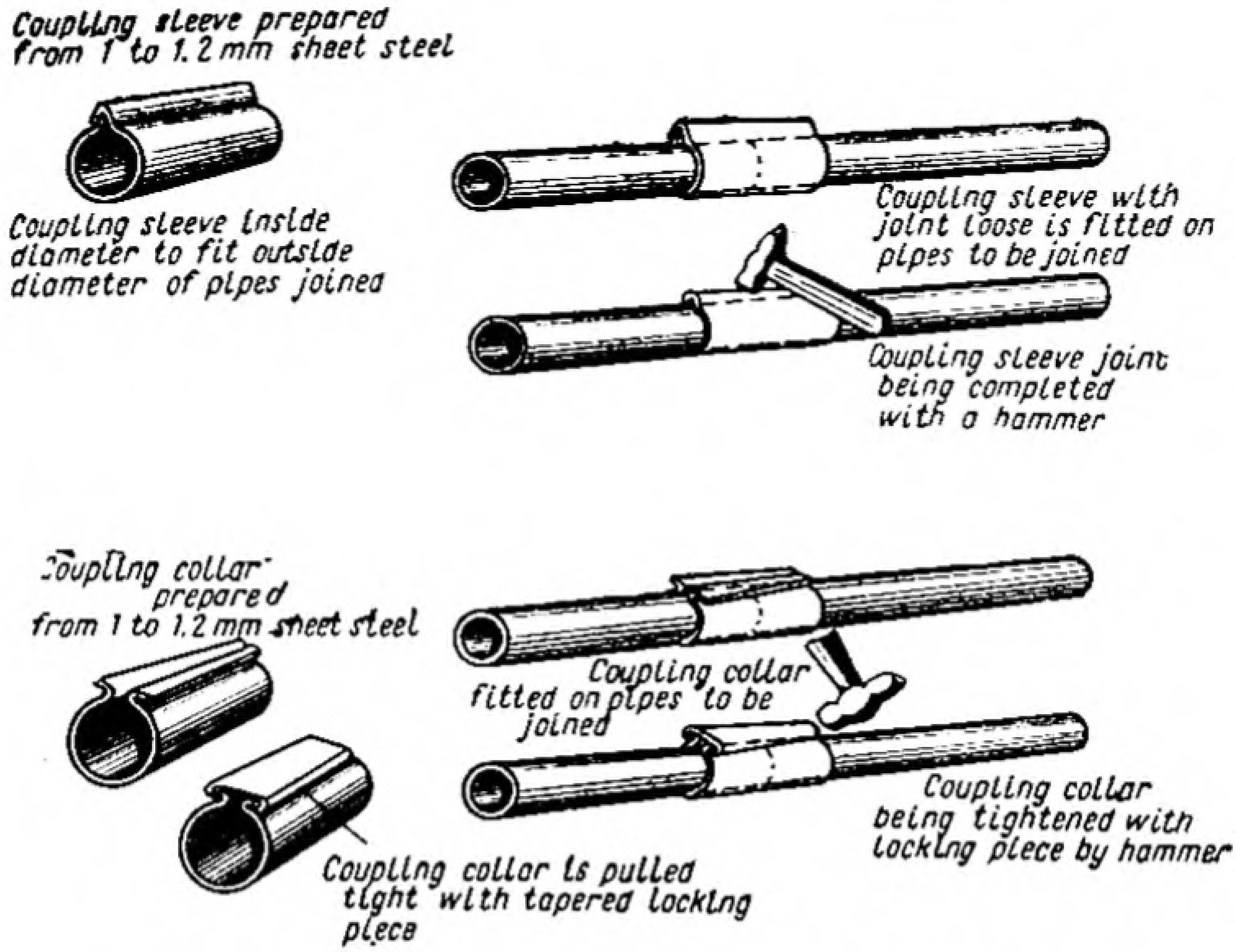


Fig. 147. Ways of joining thin-wall steel tubes.

turns are close to each other. The line is made up of three parts differing from each other in outside diameter. All the parts are made from spring-steel wire of the same diameter (Fig. 149).

The conductors are spliced and jointed at the boxes provided in the runs of conduit in the same way as ТПРФ (TPRF) wire, and СРГ (SRG) and ВРГ (VRG) cables.

Installation of Lighting Units and Switching Apparatus. When air-tight conduit is connected to lighting units, apparatus and electric motors, the connection

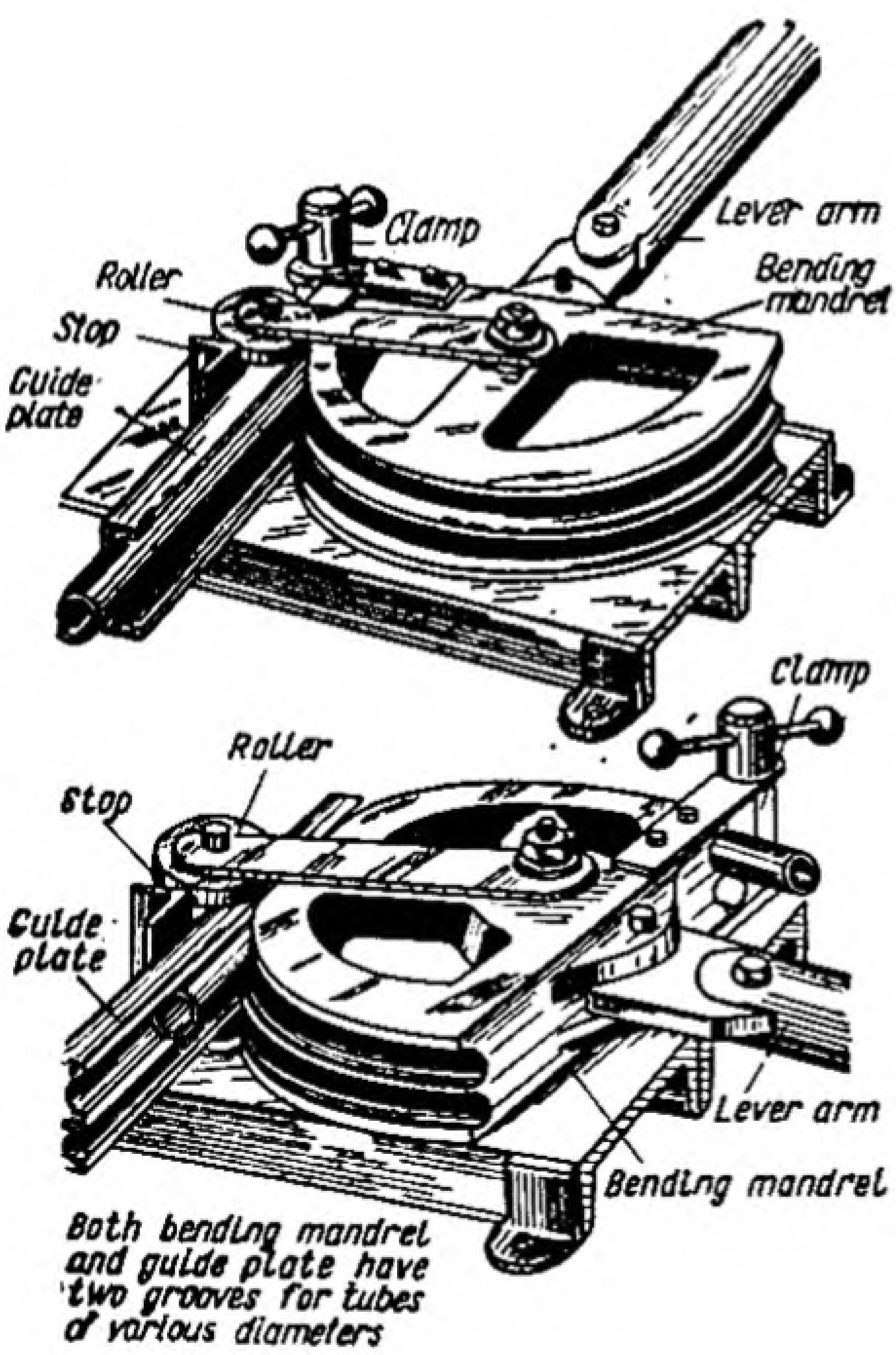


Fig. 148. Hand-operated pipe-bender for thin-wall steel tubing.

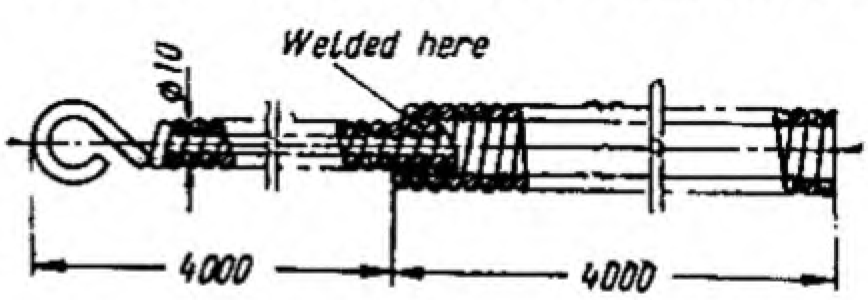


Fig. 149. Snake line for use in drawing wires into lines of conduit pipe.

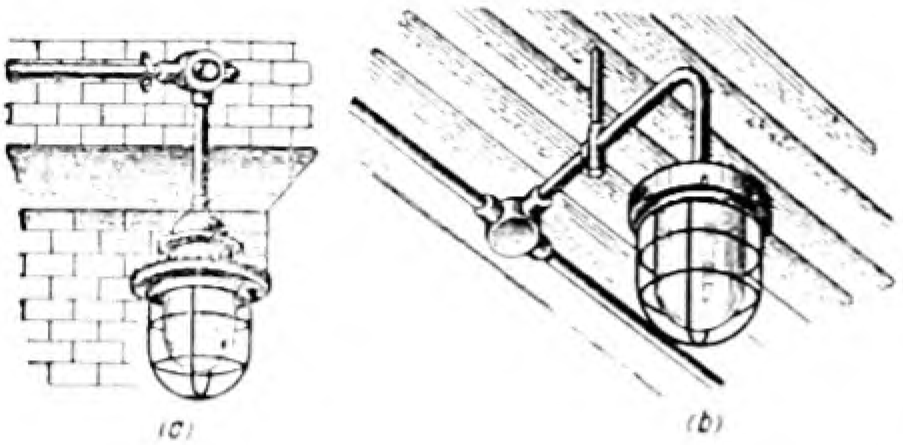
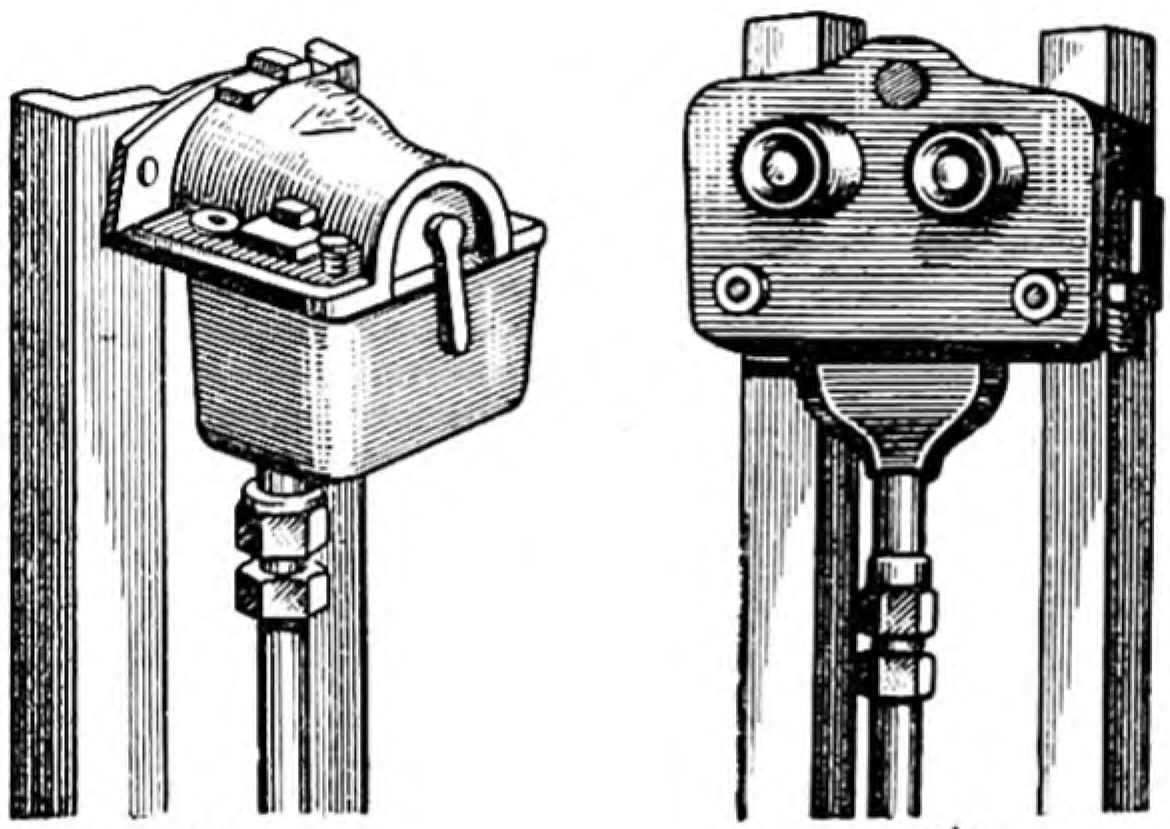


Fig. 150. Lighting units in installations requiring air-tightness:
a—at a wall drop, *b*—at a ceiling drop.

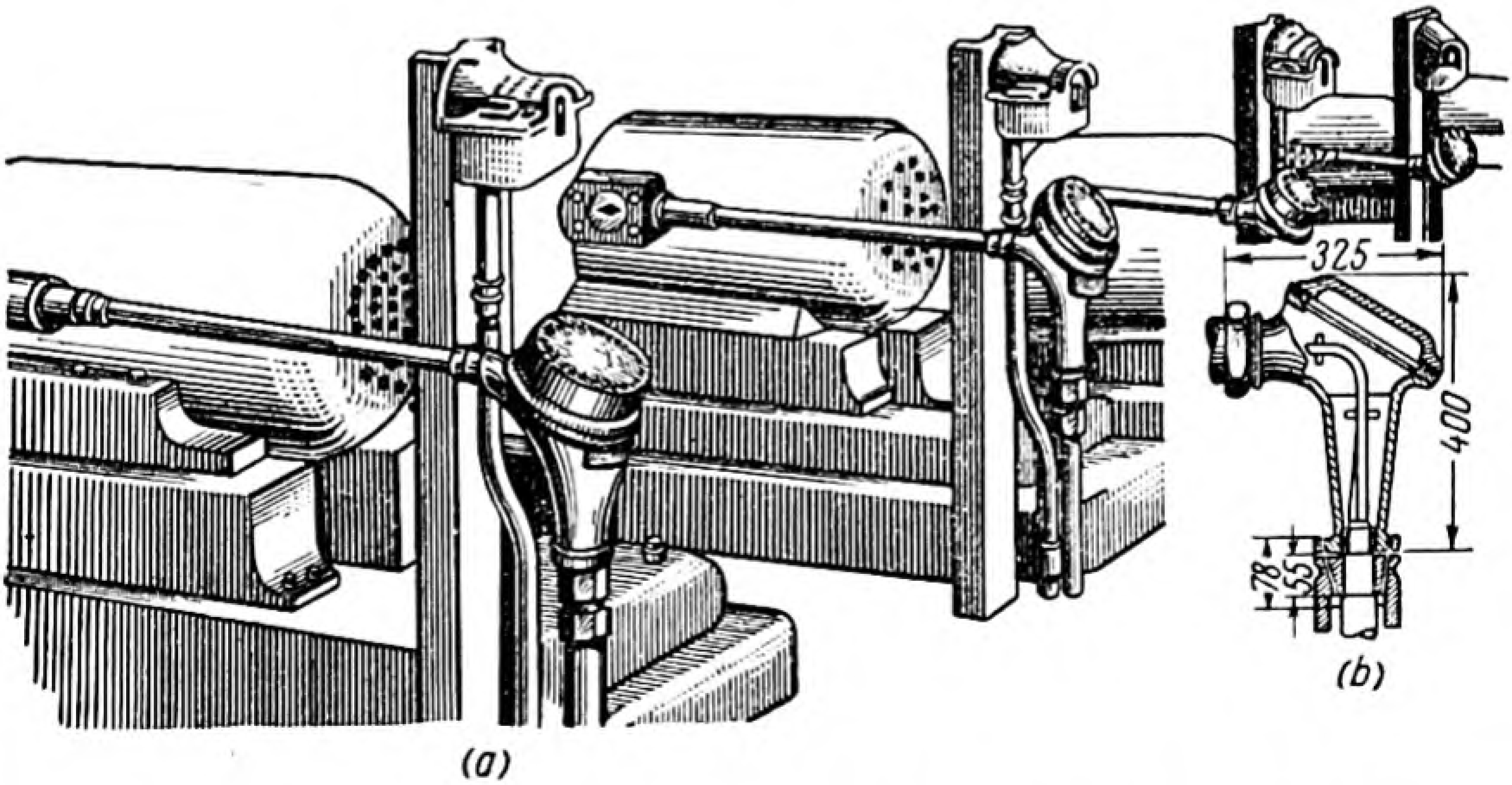
must also be air-tight, this being achieved by screw-jointing the conduit pipe to the body of the lighting unit, starting apparatus, etc. (Figs 150, 151 and 152).

When conduit piping does not have to be air-tight, the lighting fittings, switches, etc., are mounted in the same ways used for open or surface wiring.



(a) (b)

Fig. 151. Conduit piping connected to starting apparatus and a control device:
a—connection to a hermetic starter, *b* — connection to a hermetic push-button station.



(a) (b)

Fig. 152. Conduit piping connections to electric motors and starting apparatus:
a—general view, *b*—section through a jointing box.

Task 1. Draw up an operation-sequence card for the jointing of steel conduit pipes.

Task 2. Draw up an operation-sequence card for the preparation and installation of conduit pipes and the draw-in of the wires in them.

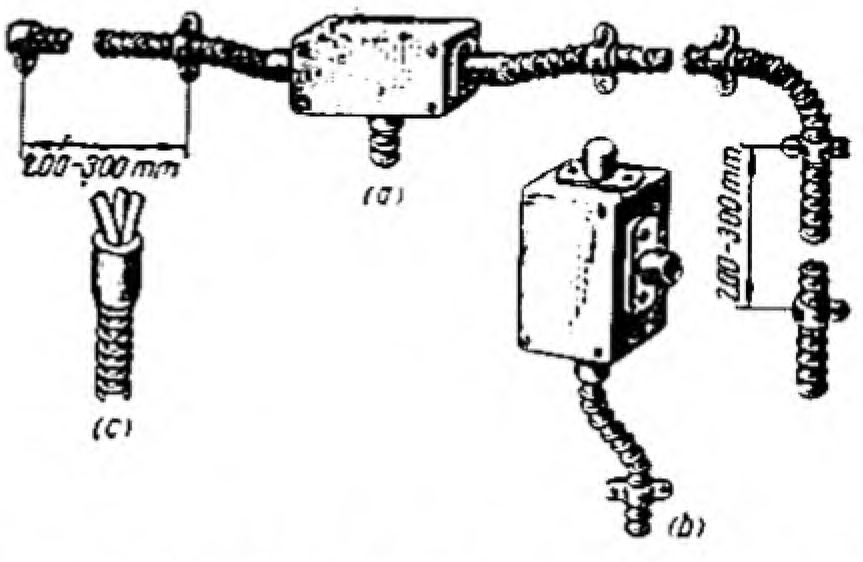


Fig. 153. Various parts of flexible metal hose wiring:
a—hose fixed with straps, b—entrance of hose into a jointing box, c—termination of metal hose with metal end bushing.

9. Installation of Wiring on Machine Tools

Wiring is installed on machine tools either in steel pipes or in flexible metal hoses.

Steel pipes are installed on machine tools mainly by the same methods used in installing them on walls and ceilings within buildings. Fixing of the pipes on the machine frames is accomplished by means of screws or bolts.

The operations performed in splicing, tap jointing and connecting the wires in the junction boxes are the same as those carried out with the wiring installed in ordinary steel conduit runs.

On machine tool frames many bends and obstacles are encountered. This makes for a certain inconvenience in installing the wiring.

The installation of wiring in flexible metal hose is a method having substantial advantages over rigid steel conduit wiring. Due to its great flexibility, metal hose is easy and simple to install at corners and pass around obstacles and to run into starting apparatus enclosures and into jointing and tap-off boxes. Hoses are secured to machine tool frames by straps which are fixed to the frames either with screws driven into tapped holes or with bolts.

The general appearance of wiring installed in flexible metal hose on a machine tool frame is pictured in Fig. 153.

Wiring installed in flexible metal hose is connected to the starting apparatus and motor of a machine by means of special entrance boxes.

Also permissible for installation on the frames of machine tools is grade ПРП (PRP) braided-wire-sheathed, rubber insulated wire which is installed in the same way as flexible metal hose.

Task. Draw up an operation-sequence card for installation of wiring in flexible metal hose on the frame of a machine tool.

10. Messenger Cable Wiring

When shops in industrial establishments are equipped with lighting systems, it is frequent practice to install the circuits in the form of messenger cable wiring. This method is particu-

larly convenient when the premises contain a great number of complicated structural elements such as glazed roofs without ceiling surfaces, many beams and a series of roof trusses.

In such premises the messenger cables from which the lighting fittings and runs of wiring are supported are stretched from one wall to another, usually in a longitudinal direction.

Messenger wiring may be installed with rubber-covered grade ПР (PR) wire supported on knob or pin insulators and with rubber-insulated grade СРГ (SRG) lead-sheathed or grade ВРГ (VRG) vinyl-sheathed cables.

A messenger cable line is usually put in with one cable, or with two cables arranged either in a horizontal or a vertical plane. First to be installed for such lines are the dead-ending or anchor stirrups fixed in the walls with cement mortar or bolted to them with the aid of through bolts.

To tension the messenger line

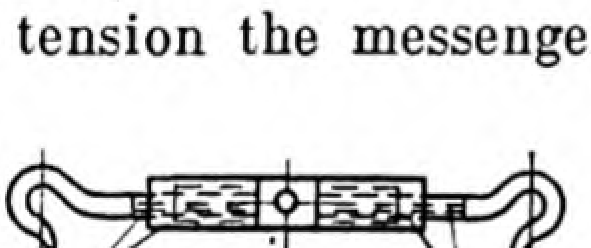


Fig. 154. Turnbuckle used to tension messenger cable.

between the anchor stirrups, the line is constructed with turnbuckles (Fig. 154) or strain bolts. If the distance between anchor stirrups exceeds 12 metres, the messenger cable is rigidly secured at 2-3 intermediate points of support to the beams or roof trusses in the premises.

When the wires are supported by knob insulators, various kinds of stirrup and other fixing aids are used (Fig. 155).

Wires supported by pin insulators are installed with the use of strip steel stirrups such as illustrated in Fig. 156.

Another possible way of wiring with rubber-covered wires is to employ special cleat type insulating supports such as shown in Fig. 157.

Grade СРГ (SRG) and ВРГ (VRG) cables are supported from messenger cables by hanger clips (Fig. 158).

Both wires and cables are installed on the messenger cables by following the same sequence observed in fixing them on wall and ceiling surfaces.

All connections, splices and tap joints in unprotected rubber-insulated wires on messenger cable lines are to be made at the insulating supports, those of cables—in the junction boxes (Fig. 158).

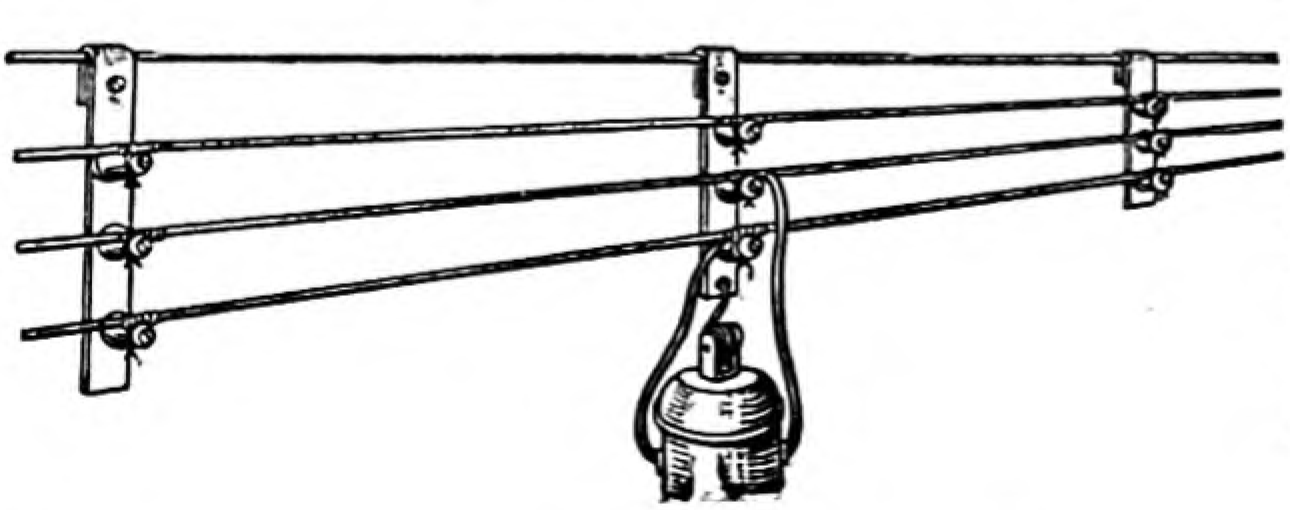


Fig. 155. Messenger cable installation made with wires supported on knob insulators fixed to strip steel hangers.

Switching devices are, as usual, mounted on wall surfaces. When the wiring is put in with grade ПР (PR) rubber-insulated wire, crossings to wall surfaces must be made with grade ПРГ (PRG) flexible-conductor rubber-insulated wire. In the case of cables СРГ and ВРГ, the crossings should be made in the form of a loop leading into a junction box fixed to the wall at the crossing point.

A method by which the installation of messenger wiring can be frequently speeded up is to install the wires or cables and the lighting fittings with the messenger line temporarily stretched at a height of 1.5 to 2 metres from floor level aud then raising the entire system in place by means of block and tackle.

Task 1. Draw up a bill of materials and list the tools and appliances that will be required for installing a messenger cable lighting circuit wired with size 2×2.5 sq mm grade ВРГ (VRG) rubber-insulated cable according to the floor plan given in Fig. 159. Explain the sequence of operations followed in performing the job. Assume the scale of the drawing to be 1 : 100.

Task 2. Draw up an operation-sequence card for a job consisting

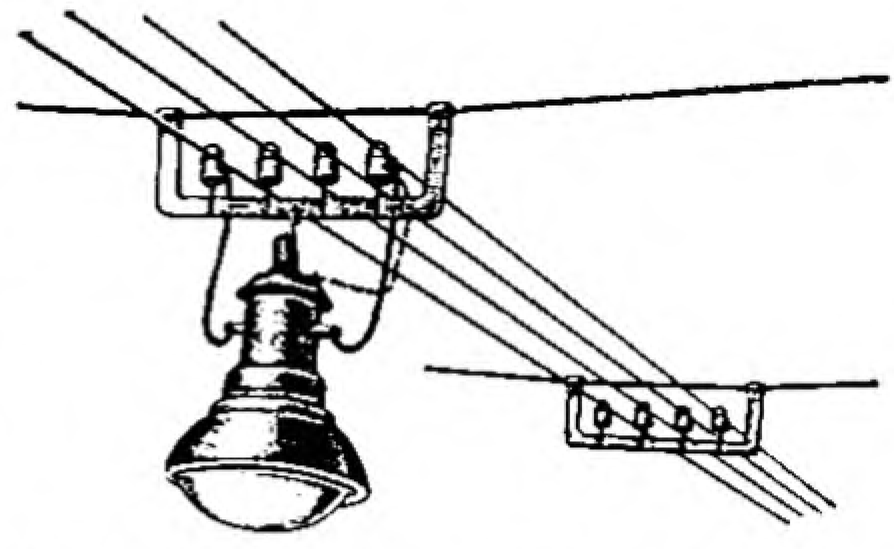


Fig. 156. Messenger cable installation made with wires supported on pin insulators fixed to hanger stirrups.

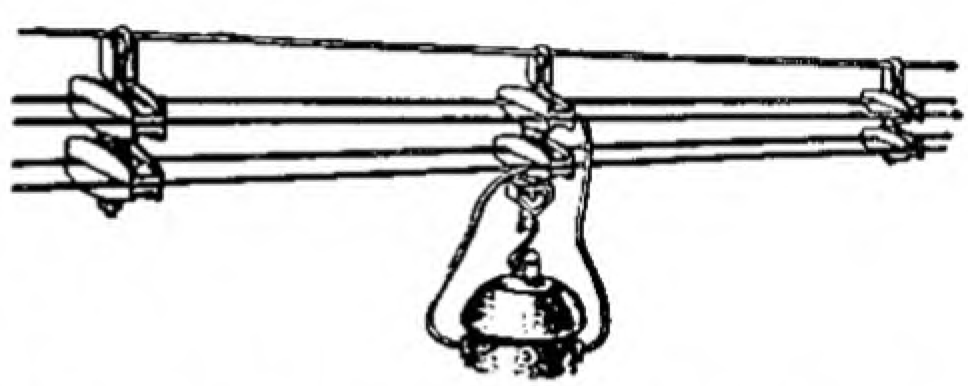


Fig. 157. Messenger cable installation made with insulating cleats.

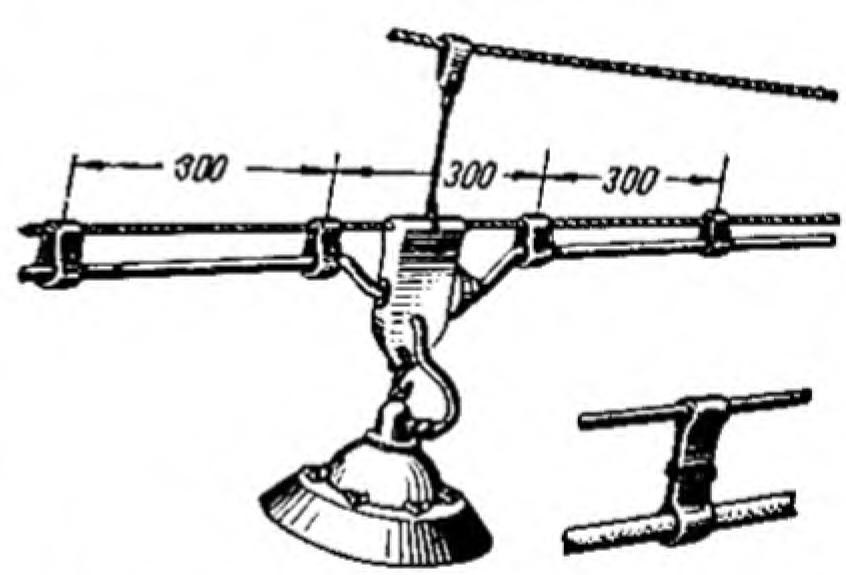


Fig. 158. Messenger cable installation wired with СРГ (SRG) or ВРГ (VRG) cables.

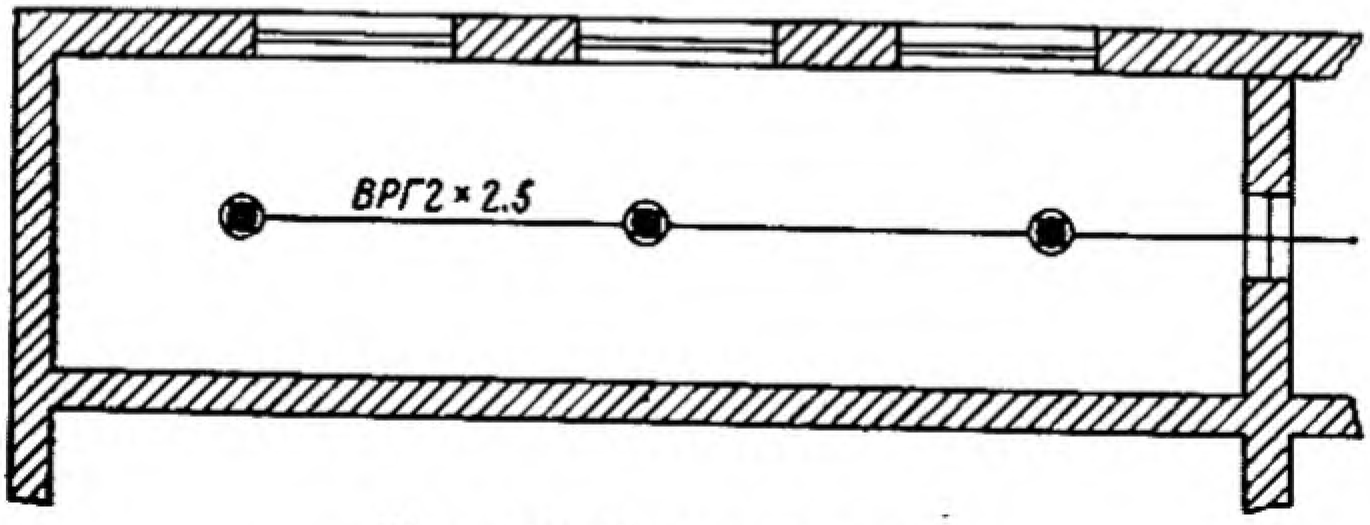


Fig. 159. Wiring floor plan.

in mounting a type ВПН (VPN) water-tight lighting unit on a messenger cable line.

11. Concealed Wiring

Concealed wiring can take the form of wires hidden under finished surfaces in semihard rubber, glass and paper tubing, and also of wires concealed without the use of tubing.

In apartment houses, in addition to the above, directly concealed wiring is put in with grade ППВ (PPV) flat p.v.c.-covered wire.

This type of wiring is installed in dry premises for voltages up to 220 volts. In industrial premises it is used very seldom.

The horizontal runs of such wiring must be installed at distances 100-120 mm from the ceiling or cornice, or at distances of 250-300 mm from floor level.

Wiring passed downward from some higher level is to be put in strictly vertical. If in such cases the wiring is run along the side of a window or door opening, it should be installed within a belt area limited to 100 mm from the edge of the window or door trim. This results in the wiring being protected from the possibility of damage by nails or spikes which may be driven into the walls of a room. In ceilings the wiring can be run from a junction box over the shortest possible line of layout to a lighting fitting outlet.

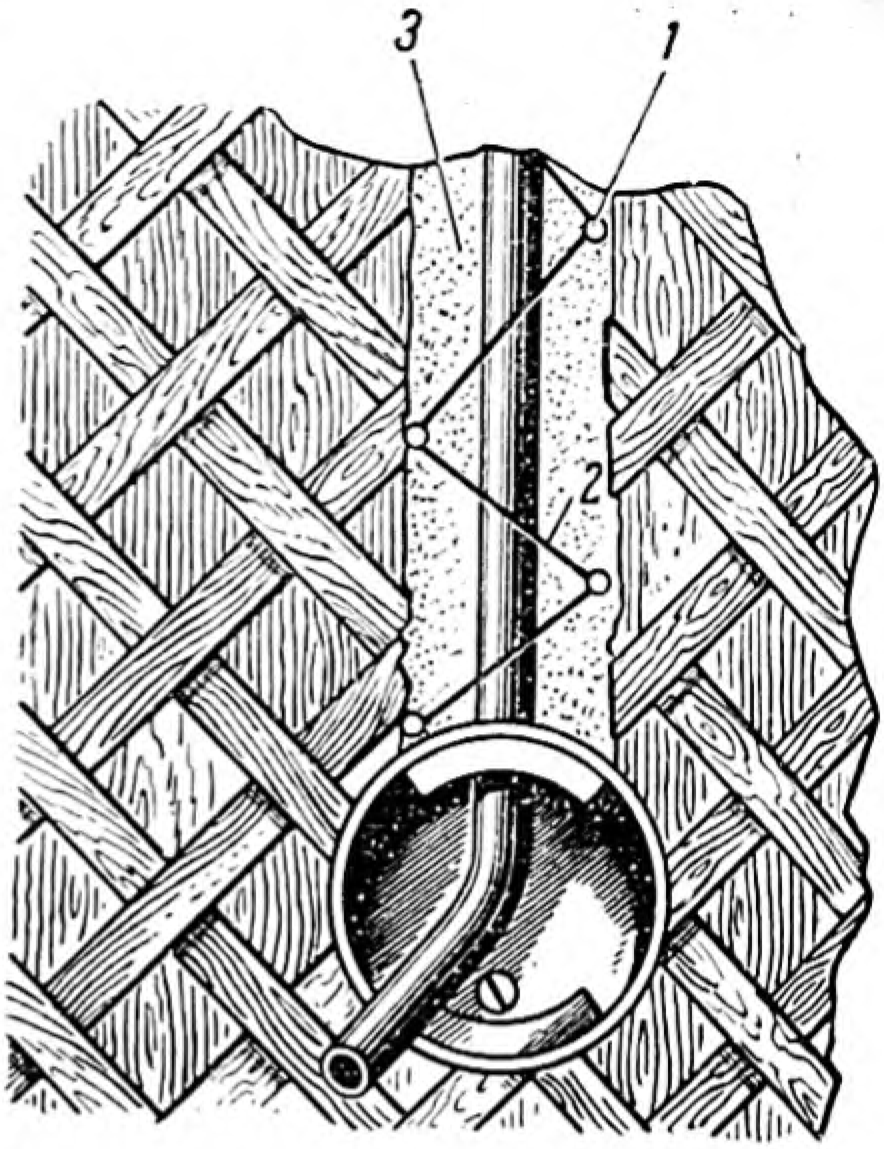


Fig. 160. Semihard rubber tubing fixed to wooden surface to be plaster finished:

1—nail, 2—lashing wire, 3—sheet asbestos underlayer.

Semihard rubber, glass and paper tubing is to be installed on wooden surfaces after first providing the tubing with either an underlayer of gypsum mortar at least 10 mm thick, or of sheet asbestos 3 mm thick. To such surfaces the tubing is secured with a cross lashing of steel binding wire and nails (see Fig. 160).

If grade ППВ (PPV) flat p.v.c.-covered wire is to be installed under plastered surfaces of wooden construction, the lathing or other kind of underlayer material must be removed from the main wooden surfaces along the entire route of the wiring over such a surface. This path should be cut from 10 to 20 mm wider than the wire to be put in. As a meas-

ure of fire-hazard prevention, the wires, over their entire routes, must be put in with a layer of asbestos under them, the layer being at least 3 mm thick and extending about 5 mm beyond the wire on each side.

Blind holes are cut in wooden walls with a special hollow borer to provide space for the junction and outlet boxes into which the concealed tubing or grade ППВ (PPV) wire is run. In brickwork and concrete surfaces, such holes are sunk with a core-type boring tool having hardened teeth (Fig. 161).

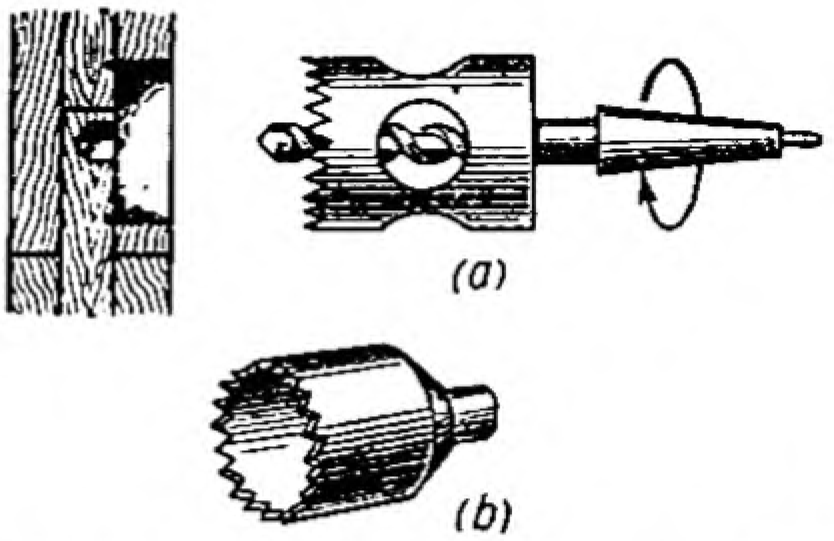


Fig. 161. Tools used to cut holes in wooden, brickwork and concrete surfaces for installing junction and outlet boxes:

a—hollow borer (for cutting holes in wooden surfaces), b—core boring tool (for brickwork and concrete surfaces).

When tubing or grade ППВ (PPV) wire must be fixed in grooved brickwork or concrete surfaces prior to being concealed, it is done by "freezing-in" with plaster of Paris mortar as illustrated in Figs 162 and 163.

Where semihard rubber tubing makes turns, or passes under an obstacle, to preclude its being flattened, it is served with a wrapping of insulating tape over which galvanised binding wire is wound in spiral form for greater mechanical strength.

Turns in lines of glass tubing are generally made by inserting jumper pieces of rubber tubing, or by using glass bent elbows.

Paper tubing at turns and ob-

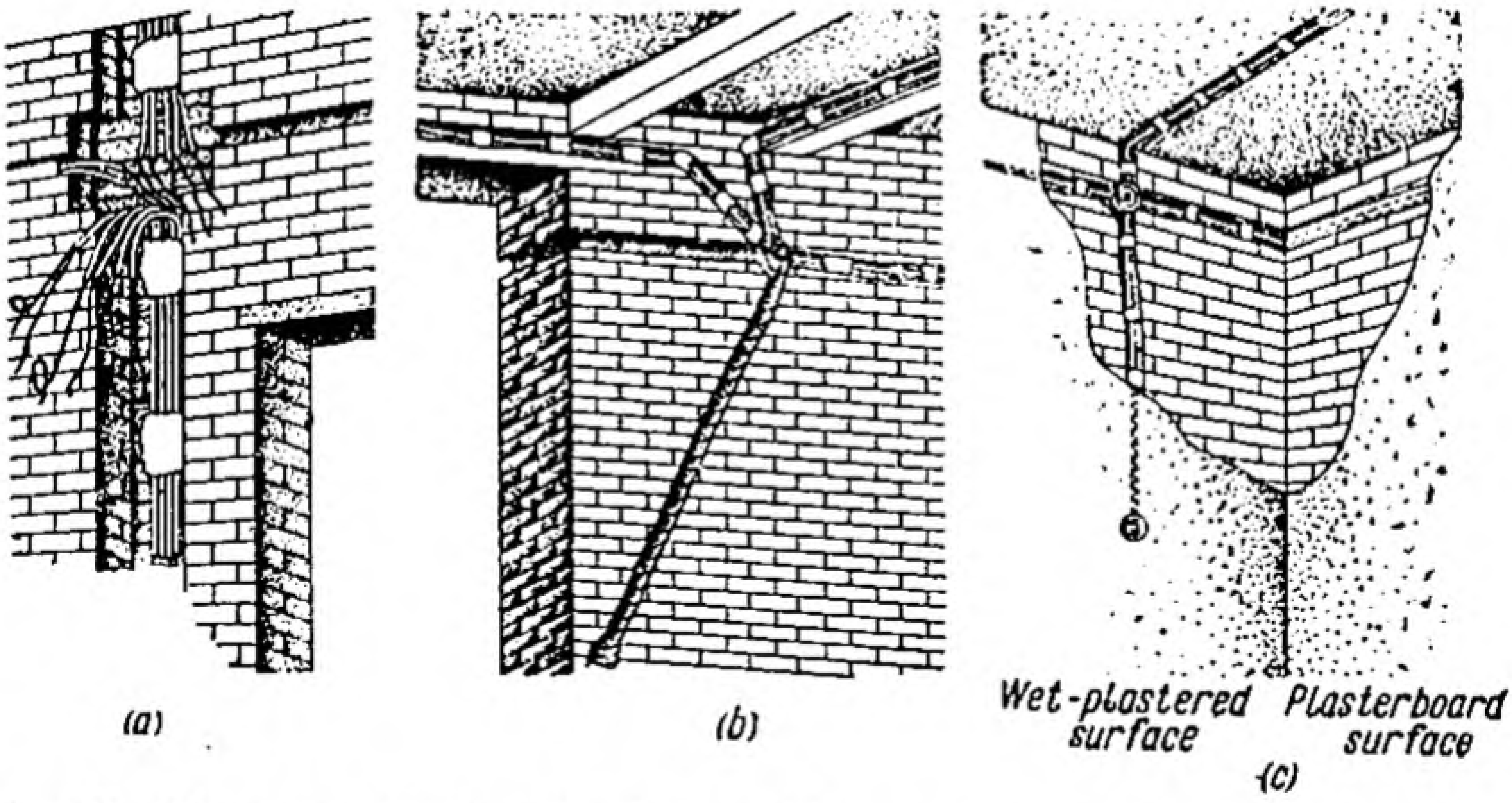


Fig. 162. Fixing of semihard rubber tubing and grade ППВ (PPV) wire by "freezing-in" with dabs of plaster of Paris mortar:

a—tubing fixed for riser runs, b—tubing fixed for branch circuits, c—fixed ППВ (PPV) wire.

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stacles is run into steel elbows or boxes.

Where a turn has to be made, grade ППВ (PPV) wire must first have the bridging film cut out from between its conductors.

Semihard rubber tubing is jointed with couplings which are simply short pieces of tubing of accordingly greater diameter. The couplings are fitted on the ends of the tubing to be jointed after first applying a coating of bitumen (tar) to their ends. In addition, the joint is wrapped with insulating tape and then dipped in heated cable sealing compound (Fig. 164). Glass tubes are jointed with couplings cut from semihard rubber tubing or with couplings made from tin plate. When tubes of large diameter must be jointed, wooden collar-couplings are used (Fig. 165).

Paper tubes are jointed with couplings made from tin plate.

At junction and jointing boxes, semihard rubber tubing and paper tubing are to be run into the box by at least 8-10 mm. Runs of glass tubing are completed at the boxes by fitting a piece of rubber tubing over the end of the glass tube and leading the rubber tubing into the box as above.

In wooden-box wall wells provided in runs of feeder wiring, when the mains wires are of large size, rubber tubing must be brought in through porcelain bushings fitted over the end of

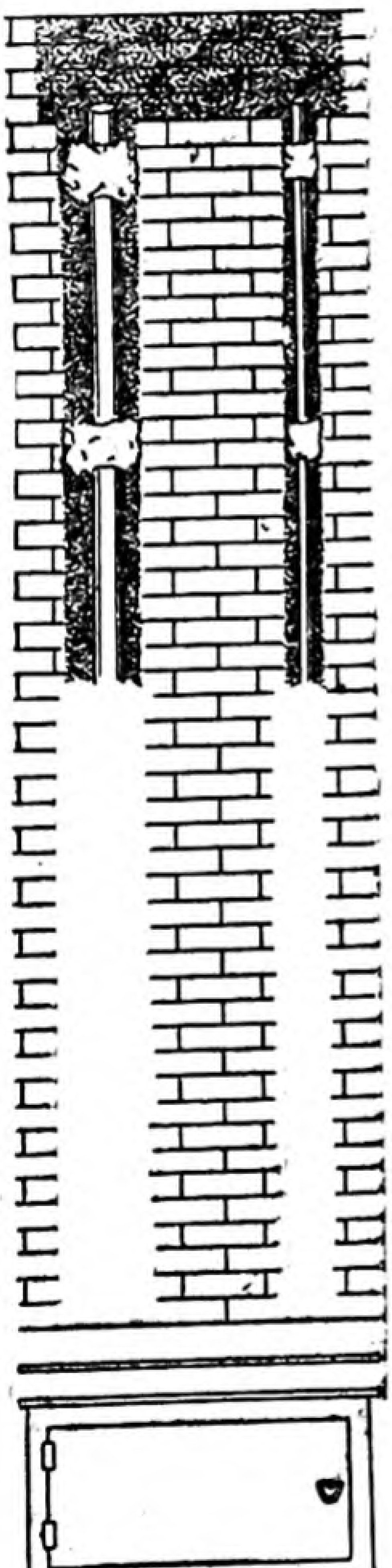


Fig. 163. Glass tubing fixed by being "frozen-in" with plaster of Paris mortar.

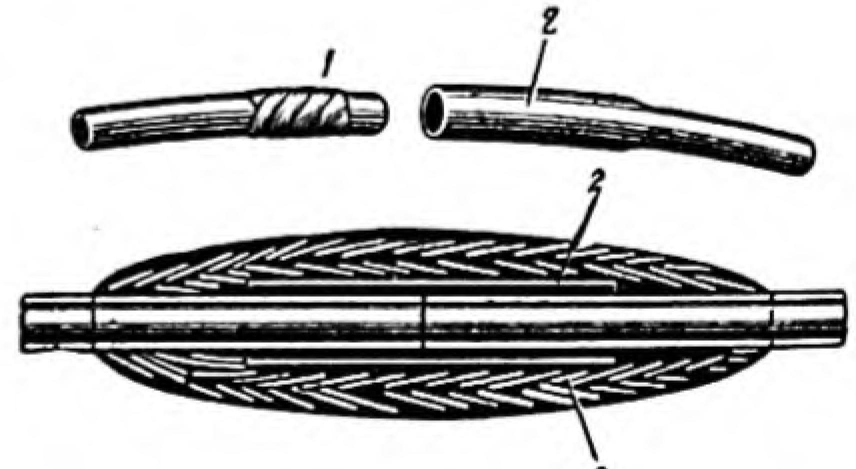


Fig. 164. Jointing of semihard rubber tubing:

1—bitumen, 2—coupling tubing, 3—serving of insulating tape.

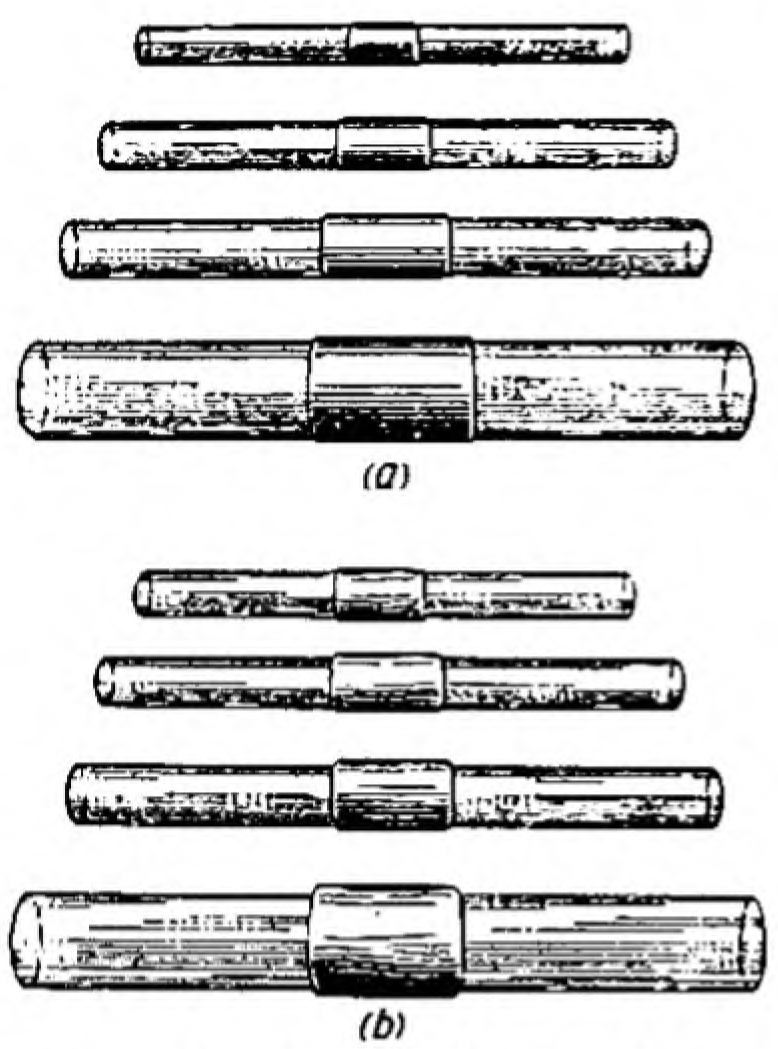


Fig. 165. Glass tube jointing:
a—with tin-plate metal couplings, *b*—with wooden collar-couplings.

the tubing. Glass and paper tubes in such cases are directly brought into the boxes and box-wells, or terminated with collars of tin plate into which either wooden bushings, impregnated with mineral oil by boiling, or porcelain bushings are inserted.

Not only junction boxes (Fig. 166*a*) but also box-wells require

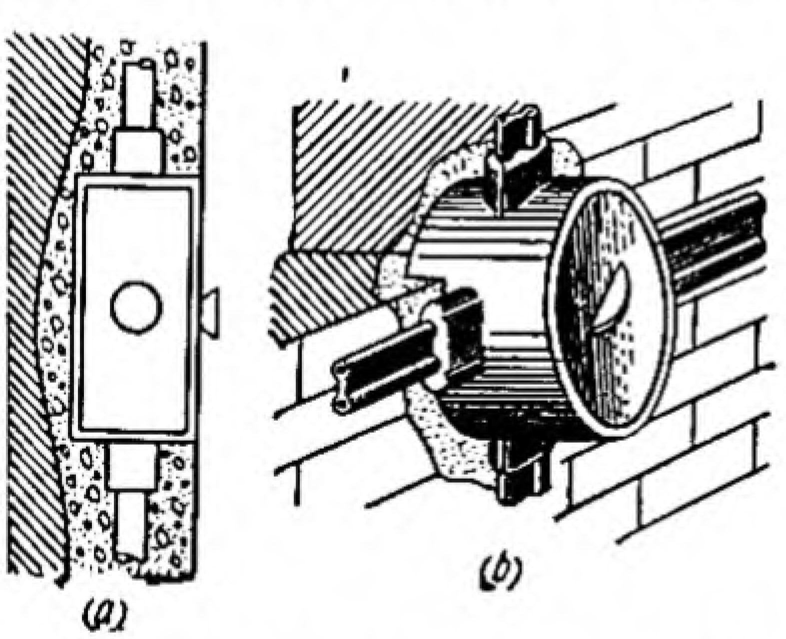


Fig. 166. Junction box mounting:
a—in installing concealed wiring with semihard rubber tubing, *b*—in installing concealed ППВ (PPV) wire.

such fitting that it leaves them flush with the plaster surface; this requirement should be borne in mind when they are cemented in.

At the points where grade ППВ (PPV) wire is brought into boxes, a porcelain bushing or a piece of p.v.c. tubing should be slipped over it. Another way is to serve the ППВ (PPV) wire with p.v.c. tape where it enters the box (Fig. 166*b*). In bringing such wire into a box, its bridging film must be cut out and the ends made long enough to be laid in with one or two turns in the box. This provides a certain reserve for possible future connections.

The wires in concealed wiring are pulled into the tubing from box to box by means of flat steel fishing wires or round steel wires. In the boxes the wires are spliced and jointed by the compression method.

When concealed wiring is installed in dry premises, a wide variety of lighting fittings may be used. They may be opal-glass fittings ("Lutsetta", ceiling-mounted "Shar"), wall brackets, ceiling-mounted fittings or ornamental chandeliers. Outlets of semihard rubber tubing to the lighting fittings in the great majority of cases are terminated by cementing in bent porcelain tubes with the funnel end flush with the plaster surface.

When the wiring is installed in concealed glass tubing, the outlets to the lighting fittings are also put in as stated above, a piece of semihard rubber tubing being slipped over the end

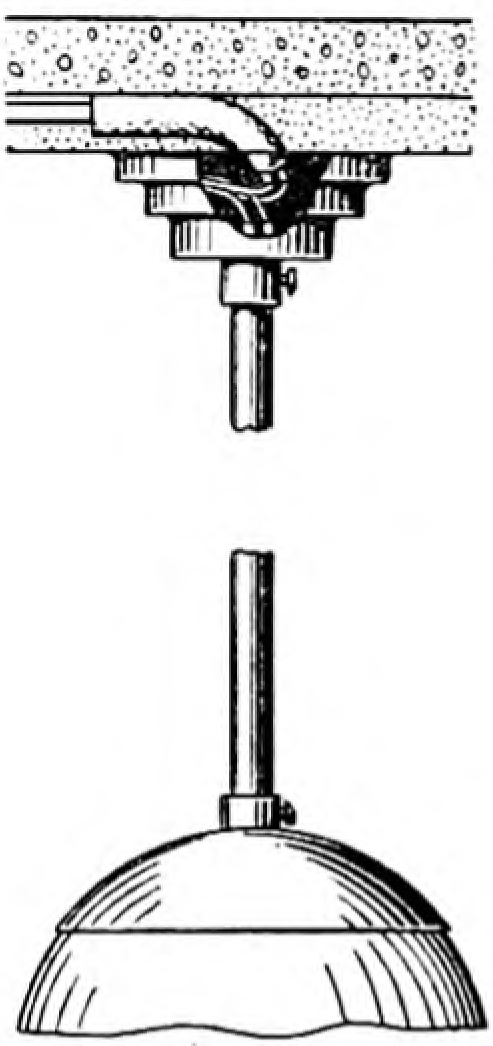
of the glass tube passed into the porcelain bent tube.

The joints made in connecting the wiring to the lighting fitting leads are to be stowed out of sight behind the wall or ceiling plate of the fitting (Fig. 167*a*).

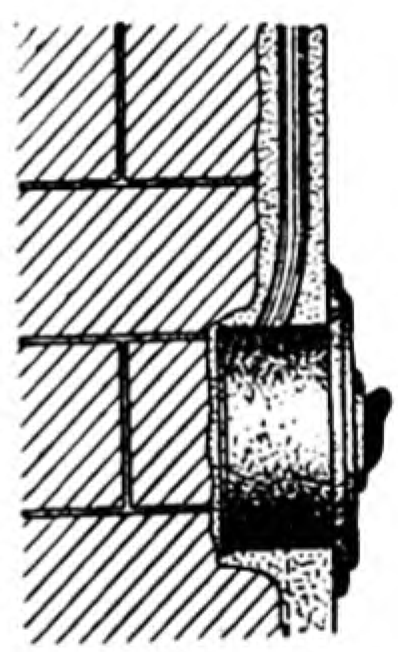
In concealed wiring the lighting switches and plug sockets can be either flush (Fig. 167*b*) or surface mounted. If the device is to be surface mounted, the concealed wiring outlet is terminated with a porcelain bent tube (Fig. 167*c*), the funnel end of the tube being put in so as to be underneath the wooden fixing rosette. An example of lead-out of concealed wiring to a fuseboard can be seen in Fig. 167*d*.

Today, to put electrical wiring work on an industrial basis and lower installation cost,

Fig. 167. Lead-out of concealed wiring to lighting fittings, switches and fuseboards:
a—connection to lighting fitting, *b*—connection to flush-mounted lighting switch, *c*—connection to surface-mounted lighting switch, *d*—lead-out at a fuseboard.



(a)



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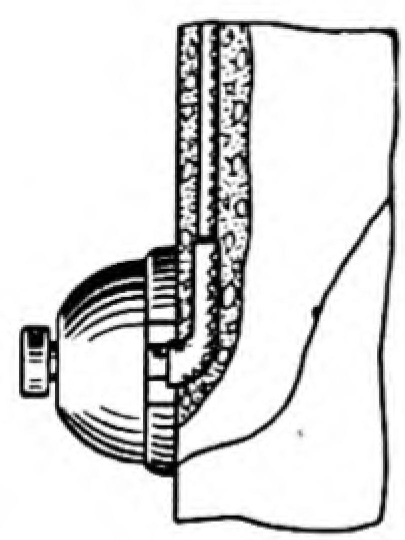

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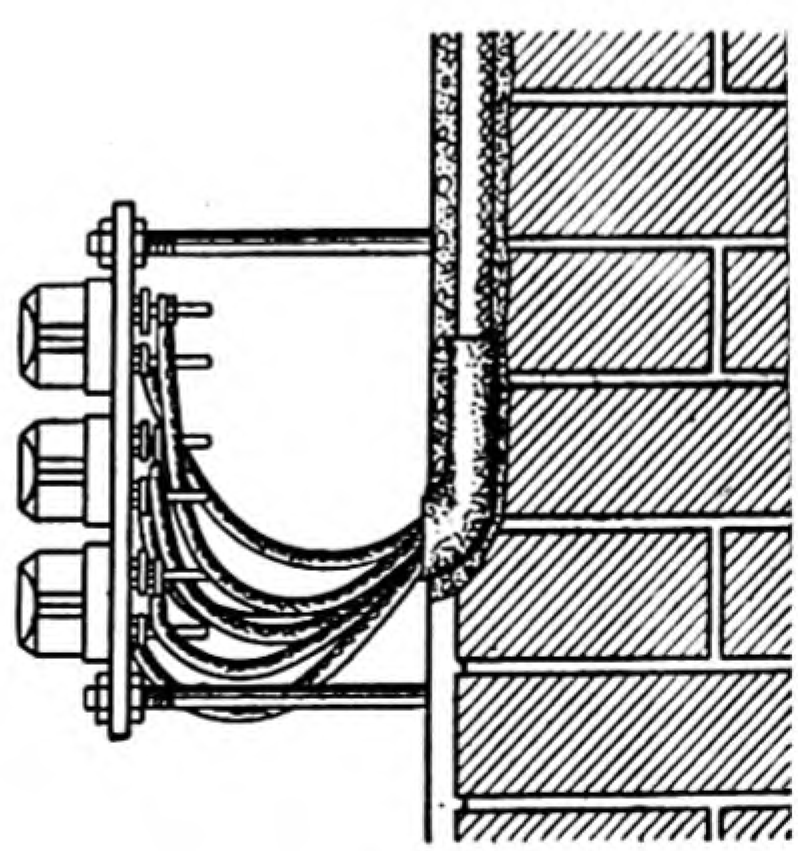

(d)

it is wide practice to put the concealed wiring in during the production of factory-made partitions on rolling-type precasting machines.

These partitions are fabricated as room partitions in special works producing ready precast structural elements. When such structural elements are prefabricated, the glass or paper tubing, as well as the junction and outlet boxes, are put in prior to precasting, following which the wires are drawn in and the switches and plug sockets are mounted.

After the factory-made structural elements have been received at a site and mounted in the structure, the work of the electrical fitters consists only in connecting the circuits according to the design drawings.

When the work is organised on these lines, installation schedules are considerably shortened. Furthermore, the cost of wiring is noticeably reduced.

Fig. 168 schematically shows the features of wall partition prefabrication with the concealed tubing and boxes for the wiring already in place.

12. Specific Features of Earthed-Neutral, Four-Wire 380/220-Volt Lighting Circuit Installation

As to safety requirements against shock hazards, earthed-neutral, four-wire, 380/220-volt installations occupy a position intermediate between low-voltage and high-voltage installations.

By reason of this, such circuits must be put in with observance of a number of special requirements.

When these circuits are installed, the metal housings of the lighting fittings, switches and other devices, the metal sheaths of metal-jacketed types

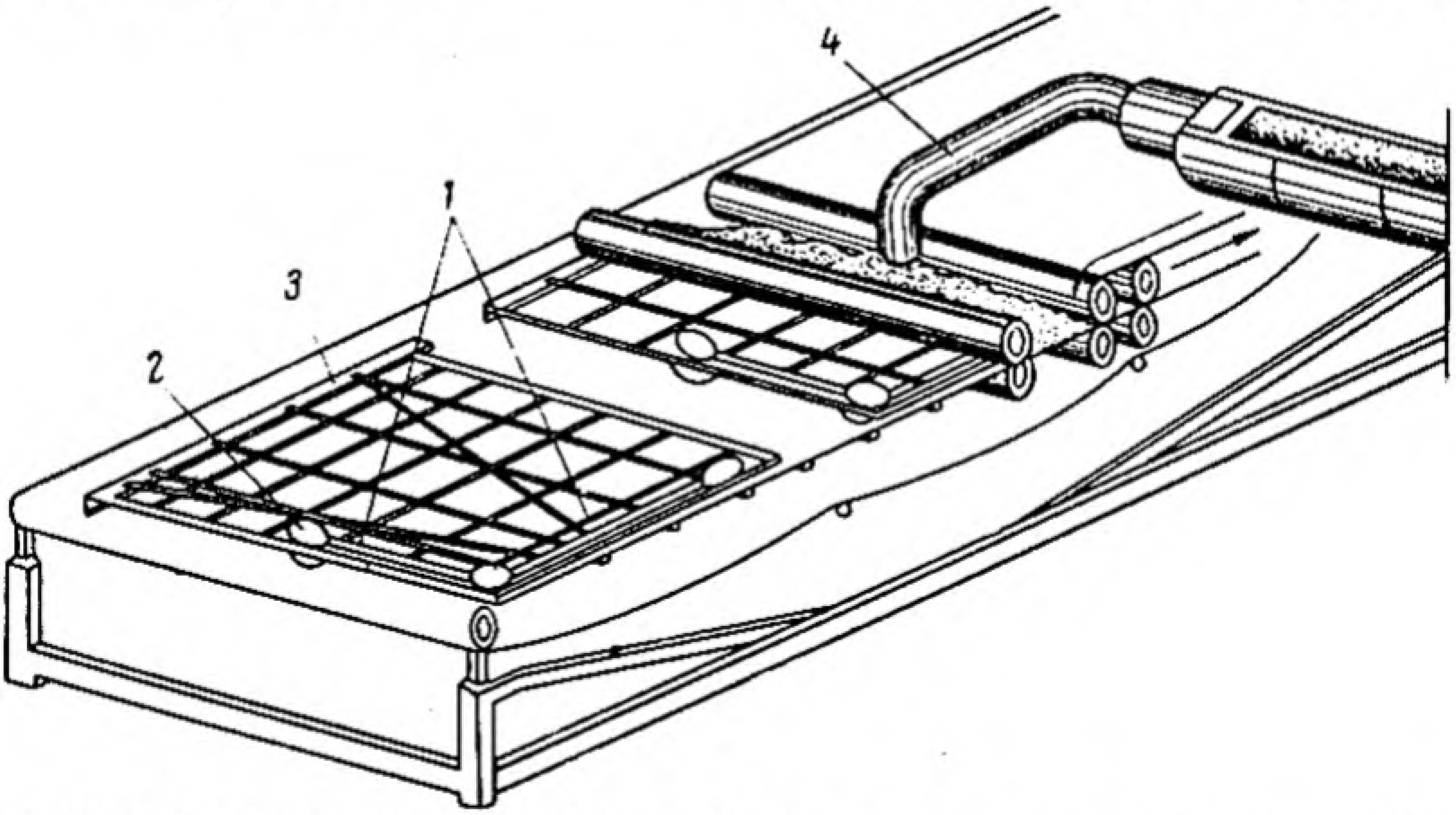

Fig. 168. Schematic representation of wall partition prefabrication with the concealed wiring tubing and boxes in place:
1—insulating tubes, 2—wiring boxes, 3—reinforcing steel cage, 4—concrete delivery pipe.

of wire, the metal sheaths of cables, the metal conduit piping and all other metal parts to which the voltage is normally not applied, but which may acquire a potential by contact must be earthed. That is, they must be connected to the earth-continuity conductor by which connection is made to the neutral point and to earth proper.

Examples illustrating the earthing connections made to lighting fittings are given in Fig. 169.

The earthing connection must be made by attaching the neutral wire, but never the phase wire, to the most accessible screw part of the lampholder.

To avoid breaking the earth-continuity part of the circuit, lighting switches must be interposed in a phase conductor.

For the rigidly fixed and insulated earth-continuity (neutral) wire to have sufficient mechanical strength, it must be at least 1.5 sq mm in size. When put into commission the circuits should have the neutral wires marked so as to identify them from the phase wires. The marking can be done by coating the neutral-wire supports with a coloured enamel paint, for example, by coating the heads of the knob insulators or parts of the pin insulators.

Task. Draw up an operation-sequence card for the job of installing a "Universal" metal-reflector lighting fitting in a knob-insulator wired circuit with a voltage of 380/220 volts.

13. Features of Meter Mounting

Meters, the instruments used to register the amount of electric power consumed by a circuit, require mounting on support surfaces which have adequate rigidity (main walls, for example) and are not subject to vibration.

The meters proper are mounted on special brackets made from strip steel (Fig. 170), or on special panelboards; in the latter case the meter is mounted on the boards together with the

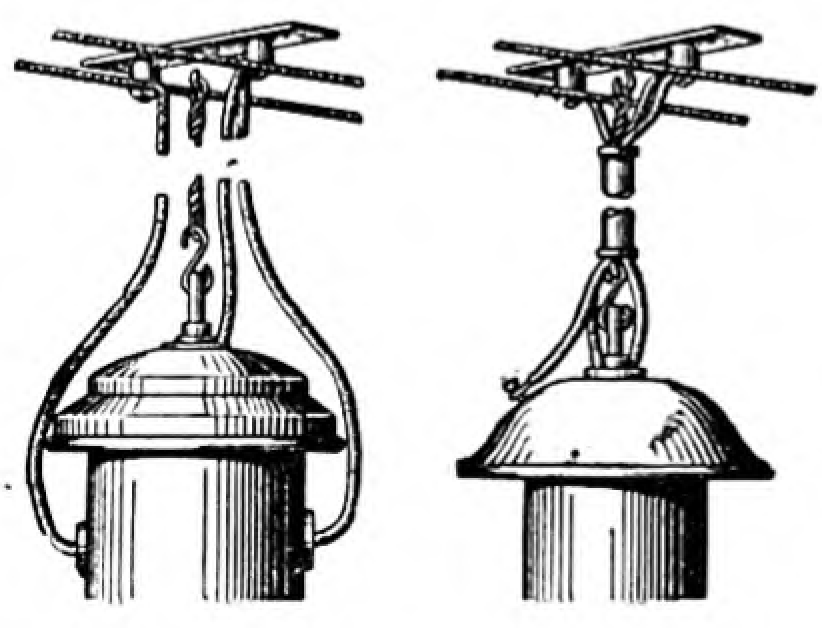

Fig. 169. Examples of earthing of lighting fittings.

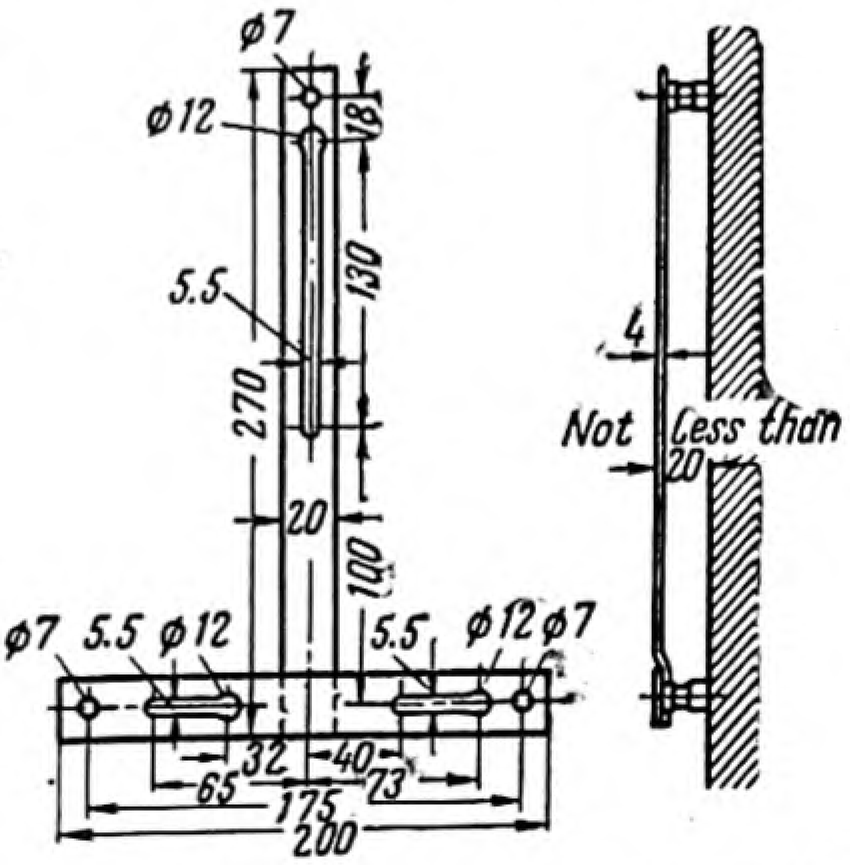

Fig. 170. Meter mounting bracket.

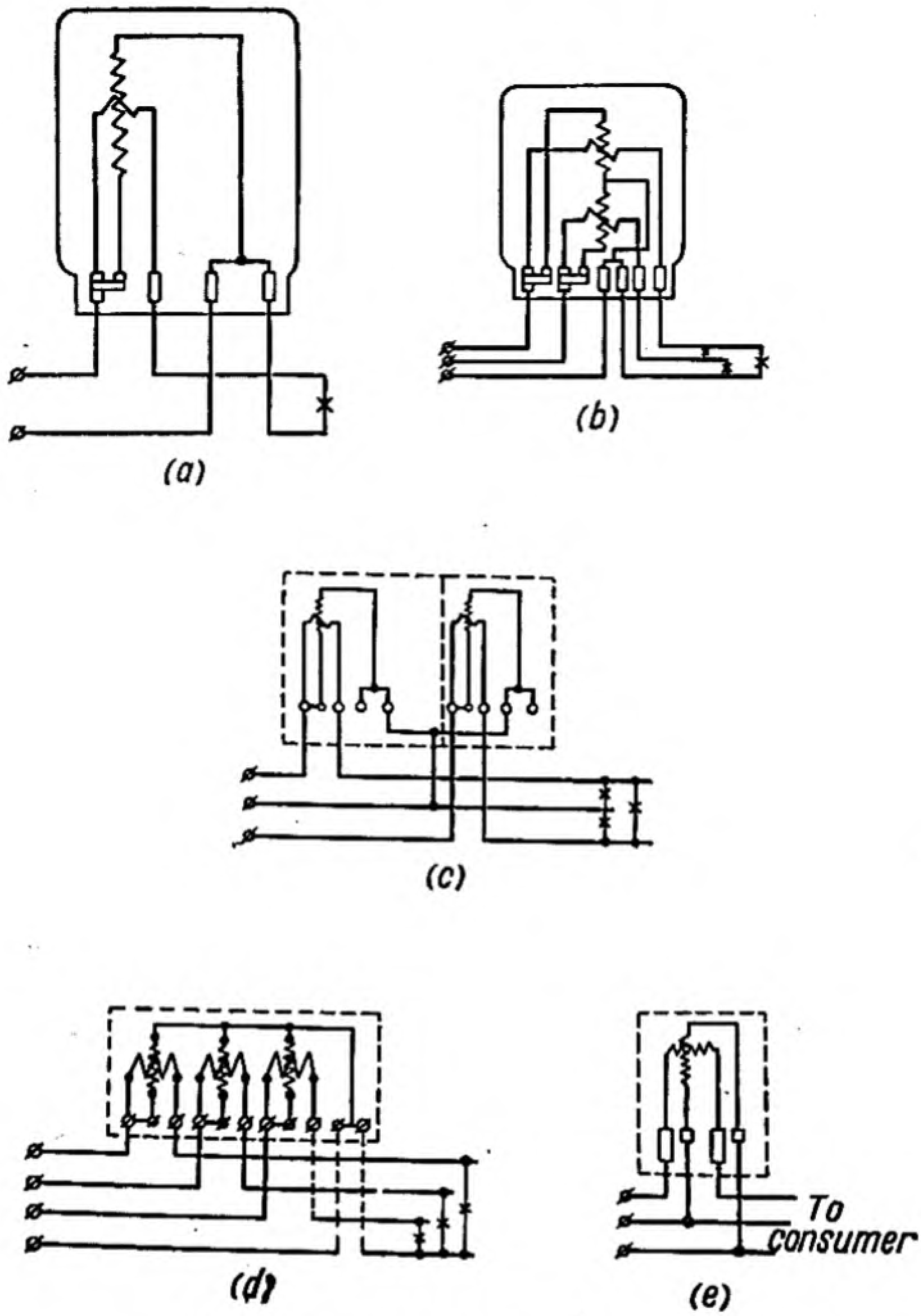

Fig. 171. Meter connection diagrams:
a—single-phase meter, b—three-phase meter, c—two single-phase meters in three-phase circuit with a balanced load, d—three-phase meter in four-wire circuit, e—single-phase meter for registering reactive power consumption.

branch-circuit fuses (refer to Fig. 49). Another method is to mount the meters in cabinets installed flush with the wall they are placed in.

In industrial establishments, where the power consumption of each shop is registered separately, the shop distribution panelboards are wired for direct mounting of the meters on them (see Fig. 47). In establishments

having centralised metering of the power consumption, the measuring is done on the high-voltage side.

The wiring at meters is generally concealed. It is brought out at the meter, for example, from undersurface runs passed through semihard rubber tubing, or from directly concealed runs of grade ППВ (PPV) wire.

Meters require mounting at a height convenient both for reading and servicing. According to standard requirements, the distance from the floor to the meter terminal box should not exceed 1,400 mm.

The most widely used meter connections are given in Fig. 171.

14. Rules for Safety During Installation of Electrical Circuits for Voltages up to 500 Volts

Before any work is commenced on an installation, the tools, plain ladders and also the step ladders must be checked for proper working condition.

Ordinary hammers and sledge hammers require checking to be sure they are firmly seated and reliably secured on their handles which must be made of some kind of hard wood (beech, maple, oak, etc.). Cold chisels, rod chisels and drift drills should not have ragged striking ends and should be well dressed. Cold chisels should have a length not under 150 mm. The minimum length of rod chisels and drift drills ranges from 500 to 650 mm.

Pliers, end-cutting nippers, flat-nose pliers and screwdrivers are to be fitted with insulating handles. Attention must always be paid to using spanners which are precisely of the size of the nut or bolt head to be engaged.

Plain and step ladders should be made of strong species of wood and have rungs and steps with tenon and mortise joints, and should also be fitted with footing pieces precluding slipping on floor surfaces. Step ladders must always be fitted with locking hooks or a chain.

Plain and step ladders may be used to do work at heights only up to 4 metres. For work with pneumatic or electric hand tools they may be used at heights up to 3 metres. At greater heights installation work must be carried out from special work platforms built of planks at least 50 mm thick. These platforms are to be made with a railing 0.75 metre high and toe-boarding 100 mm high around the edges. The toe-boarding prevents instruments and materials from falling when they are pushed and slide toward the edge of a platform and eliminates a cause of serious accidents.

Never stand a ladder on barrels, boxes and any other objects, or work when standing on the two upper steps of a step ladder. The flooring of a work platform must have a width not less than one metre.

Goggles to protect the eyes and mittens to protect the hands must be worn when driving blind holes, grooves and through holes. Driving of through holes should

be done only from a work platform and under no conditions from plain or step ladders.

Care must always be taken to make sure that electric hand tools, installer's appliances having electric drives, and all the starting devices of such tools and appliances are reliably earthed.

When work is performed in heightened shock hazardous and highly shock hazardous premises, portable lamps must receive supply, in the first case, at a voltage not over 36 volts, and, in the second case, at a voltage not over 12 volts.

All temporary electric circuits must have no bare live parts, or faulty lampholders and switches.

When working with a soldering torch, care is always to be taken to charge it only with the fuel for which it must be used. Under no conditions should a kerosene soldering torch be charged with petrol (gasoline). Prior to igniting a soldering torch, care should be taken to make sure it is in fit operating condition. The torch tank should be filled to not more than three-quarters of its capacity and the filling plug screwed in by at least four thread pitches.

Never allow a soldering torch filling plug to be screwed out and the torch taken apart until it has fully cooled down.

Soldering torches must be inspected and serviced at least once a month. Any soldering torch found to be out of order must be immediately turned over for repair.

Chapter IV
BUSWAYS

1. Open Busways

When power mains are to be installed in industrial works and factories and points of power take-off are altogether absent or few in number, it is expedient to install them as open busways, using bare wires or bus-bars as the conductors. The busways in these cases are generally arranged at a height which precludes any possibility of coming into contact with the bare current-carrying parts.

Bare wires are used for open busways where the size of each phase conductor does not exceed 150 sq mm; they are installed by conventional methods on pin-type insulators (Fig. 172*a*). As a rule, bus-bars of copper or aluminium are employed when cross-sectional areas greater than 150 sq mm are required. The bus-bars are generally installed on smooth, post (trolley-conductor) insulators, or on insulating cleats of special form, these insulating supports being secured to fixed metalwork (Fig. 172*b*).

Installation of the busways is begun by laying out and marking off the places where the metalwork parts must be fixed to support the insulators.

If a busway is to be mounted along a line of shop columns,

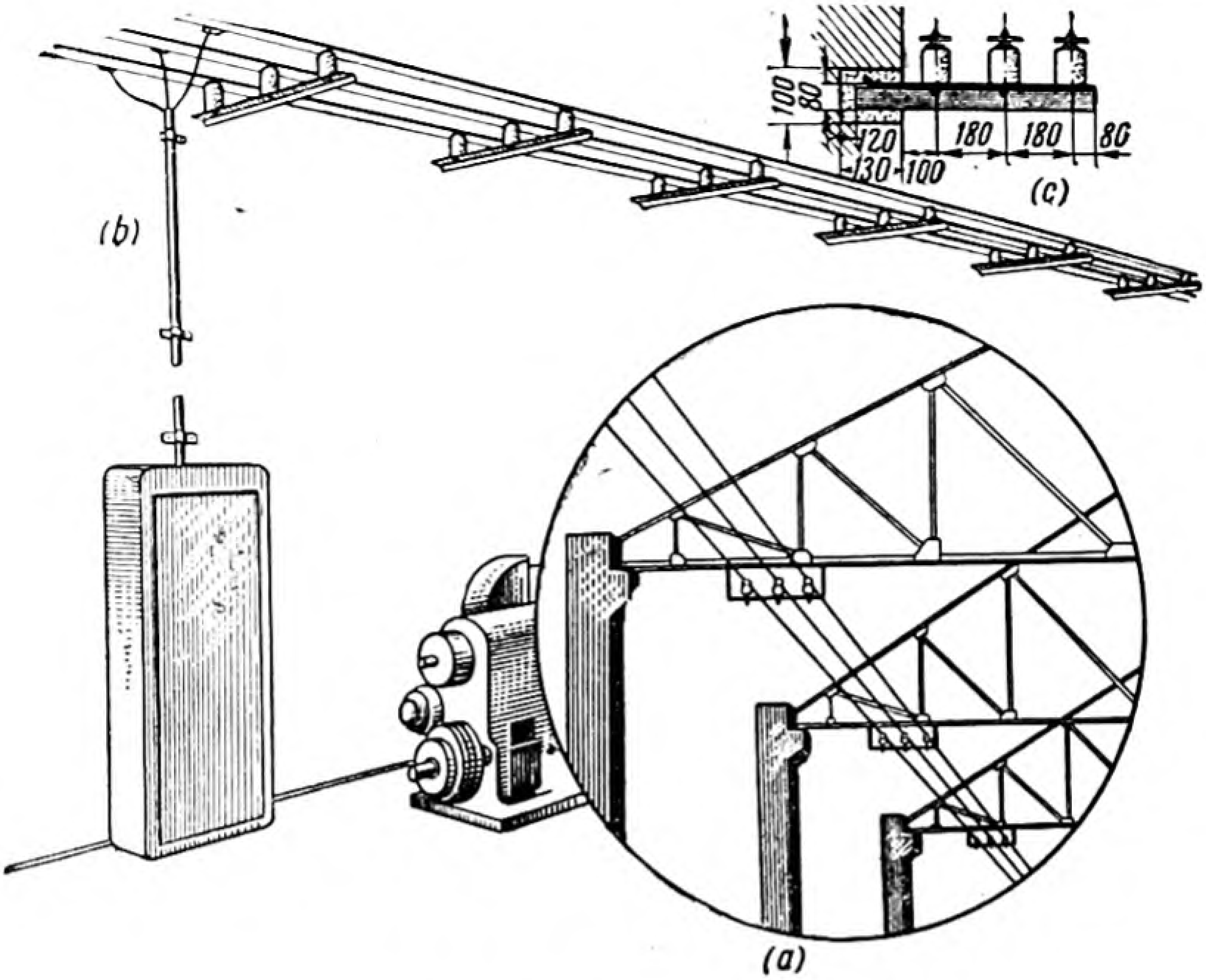

Fig. 172. Open busways:
a—open busway installed with bare conductors supported on pin insulators, *b*—busway consisting of bus-bars supported by smooth post insulators, *c*—one form of metalwork used for busway support.

the fixing height is marked off on all the columns at the same distance from floor level, or the ceiling, or from any like-type members at the same elevation on the columns to ensure that the support metalwork assemblies will all be at the same height.

The support metalwork assemblies proper may be directly anchored in walls with cement mortar (Fig. 172*c*), or be fixed with anchor studs also grouted in with cement mortar. When support metalwork is mounted on concrete partitions, it can be fixed with through bolts. On columns support metalwork is, as a rule, secured with the aid of strain bolts as shown in Fig. 173.

The insulators can be installed both prior to or after fixing of the support metalwork. Each set of insulators, when installed, should be checked for verticality with a plumb-bob line and levelled with a spirit level. The general aligning of a line of insulator sets is accomplished with a string stretched from the extreme insulator at one end to the other insulator at the opposite end.

Bus-bars prior to installation require thorough straightening, this being done on a channel or I-beam by means of a wooden mall or a hammer, and an alumin-

ium striking pad. The joints between the bus-bars are made either with bolts or by welding. In Part Four, "High-Voltage Substations", the installation of busbars will be discussed in more detail.

Task. Draw up an operation-sequence card for the mounting of support metalwork (Fig. 173) for installation of an open busway.

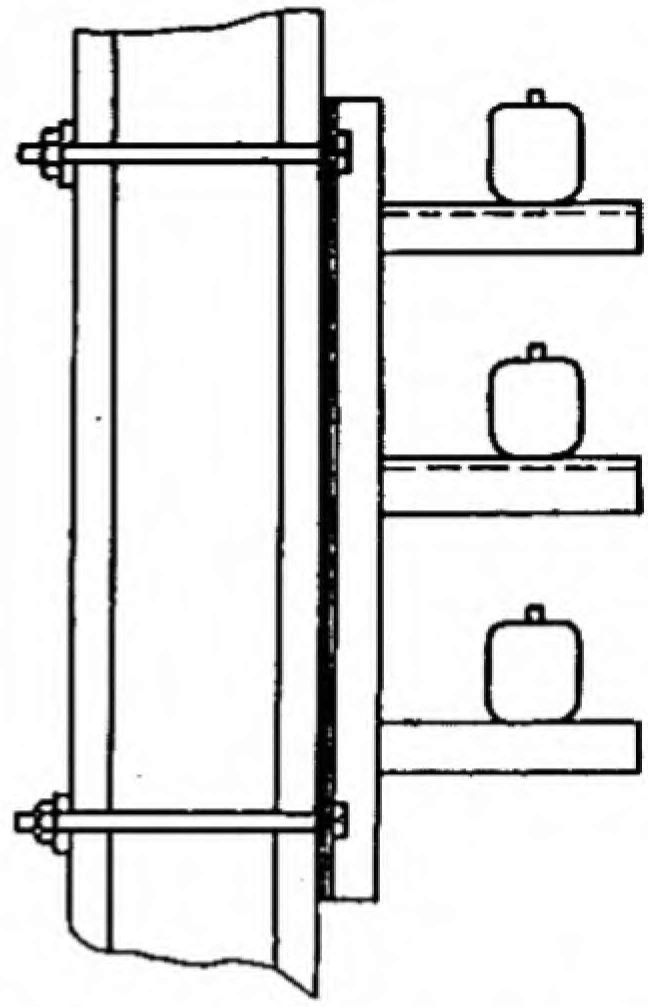

Fig. 173. Column-mounted metalwork for busway installation.

2. *Enclosed Busways*

In manufacturing shops in which the busways serve to feed a large number of loads, the busways are installed at the least possible height to shorten the length of the tap-off runs. This precludes the use of open busways.

The enclosed busways used in shops of the above type take the form of systems of separate normal-length and short-length busways sections* (Fig. 174).

Such sections have a casing 185×98 mm in size fabricated from sheet steel 2 to 3 mm thick.

Tap-offs from the busways are made by installing type OK-1 or OK-2 boxes on the casing, the first type of tap-off box being supplied only with terminals for connection of the tap-off wiring. The second type of tap-off box is supplied both with a set of fuses and terminals.

It is also possible to install a type ЯК-60 (YaK-60) tap-off box at the points of connection to the busways. This type of box has a hinged cover to which the fuse cartridges are secured. When the covers of these boxes are opened, they disconnect the tap-off run from supply (Fig. 175).

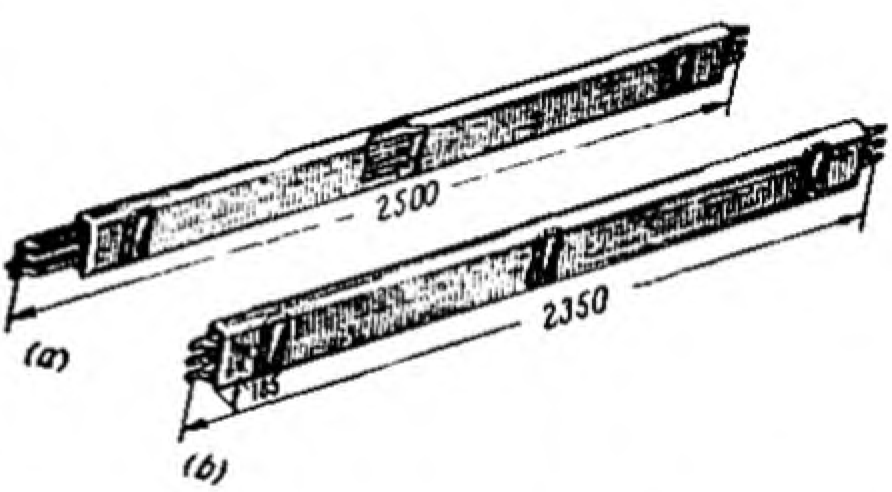

Fig. 174. Sections of enclosed type busway:
a—normal-length section, *b*—short-length section.

In addition to the above ways of tap-off, when it is necessary to supply large-capacity power consumers or feed a group of power consumers, use is made of spe-

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* According to the U.S.S.R. State Standards the busways should consist of three-metre sections.

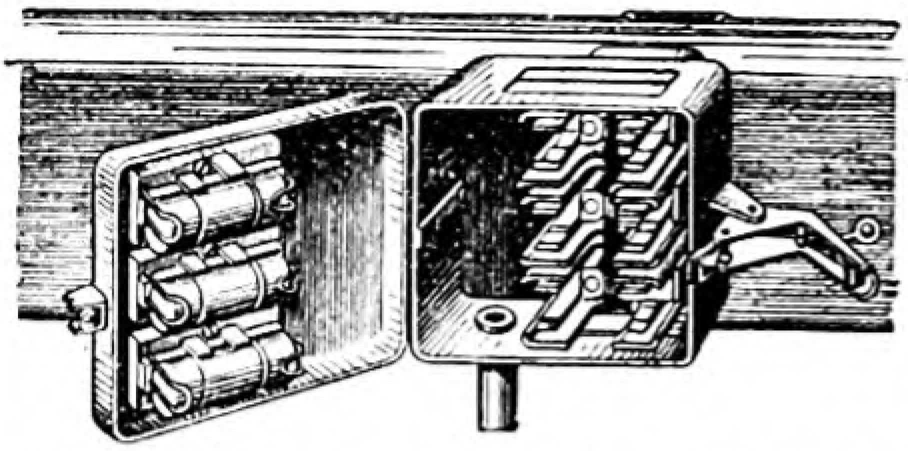


Fig. 175. Type ЯК-60 (YaK-60) tap-off box.

cial cabinets containing sets of fuses.

The arrangement of an enclosed busway system showing the use of the characteristic components is given in Fig. 176.

Where the brackets serving to support the busways are wall mounted, they are fixed to the wall with cemented-in or through studs. Such brackets must be aligned for verticality and horizontality by means of a plumb-bob line and a level.

As this work progresses, the busway is installed by joining two or three sections together before raising them onto the brackets and fixing them in place.

Wire rope hangers used to support busways are generally tensioned with turnbuckles and also braced at columns. Runs of busways along lines of columns are first joined for installation into sections equal to the centre-to-centre distances of the columns and then lifted into position.

Lead-downs from the busway to separate units of equipment are made in the form of conduit pipe runs.

Widely practised in large manufacturing establishments is the use of underfloor busways. A picture of such an installation is given in Fig. 177.

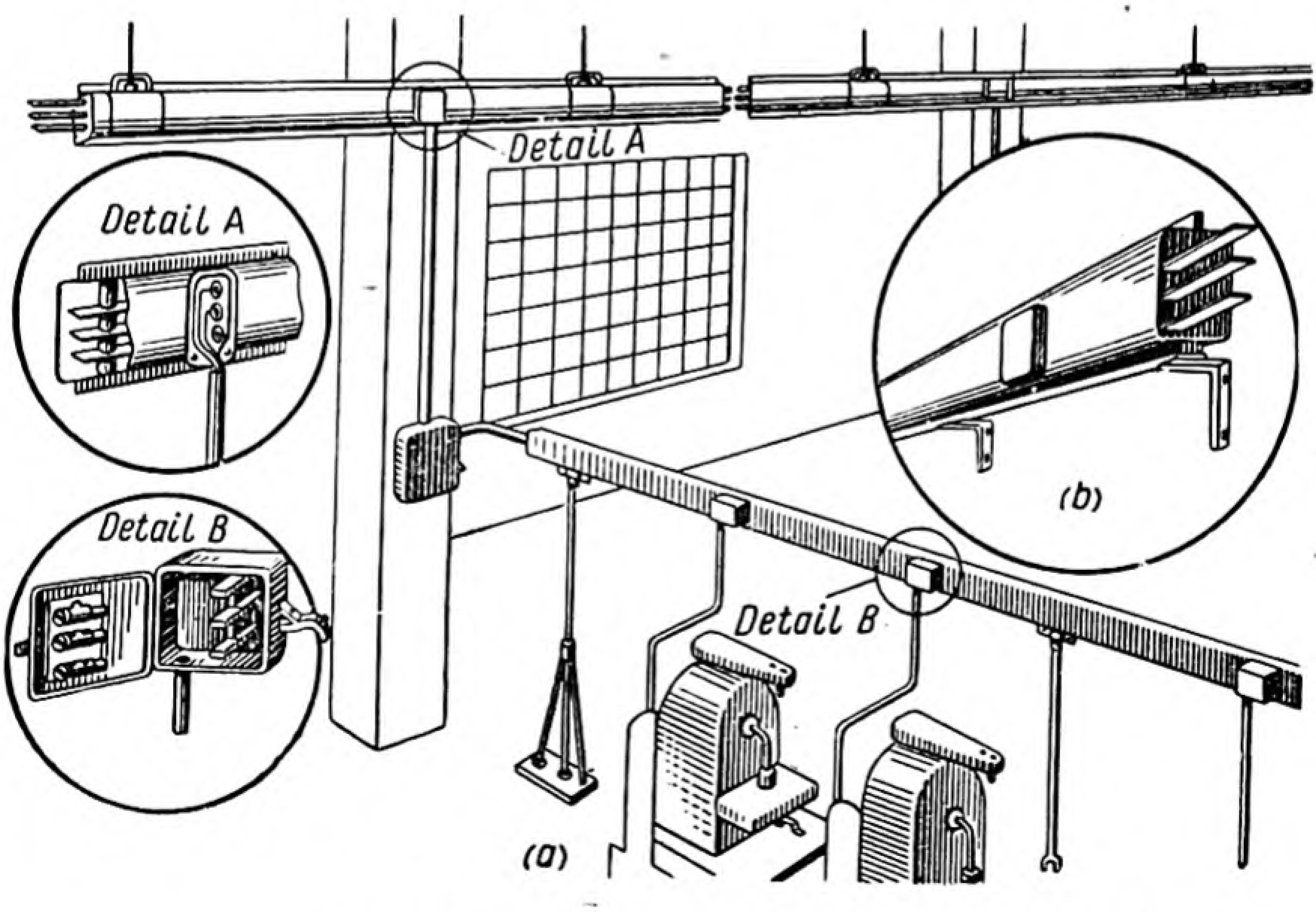


Fig. 176. Enclosed busway installed in a manufacturing shop:
a—suspended busway and post-mounted busway, *b*—busway supported by brackets.

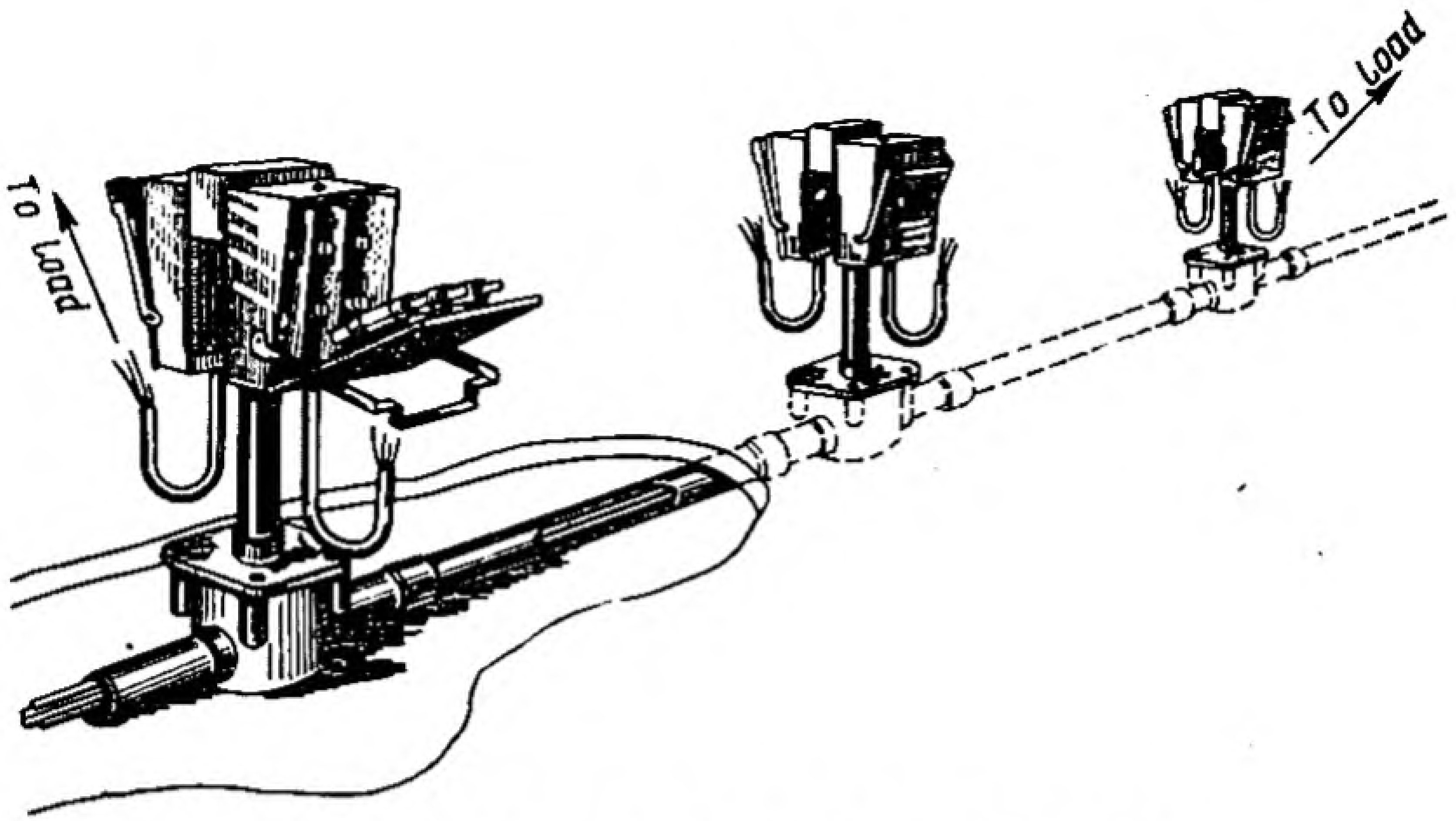


Fig. 177. Busway installed below floor level.

Another form of busway, still in the stage of development, is based on a packet design of assembly in which the bus-bars are separated from each other by a thin layer of epoxide-resin compound. This kind of construction greatly reduces busway dimensions.

Task. Describe what sequence of operations is needed to install between points *A* and *B* the section of busway shown in Fig. 176.

Part Three

CABLE AND AERIAL LINES

Chapter V

ARRANGEMENT AND INSTALLATION OF CABLE LINES

1. General Features and Elements of Construction of Paper-Insulated Power Cables

Power cable lines owe their development to the growth in length of power distribution circuits which in the earlier days of power distribution took the form of aerial lines. With time the lines became a nuisance because their circuits encumbered city streets (Fig. 178) and the territories of industrial undertakings.

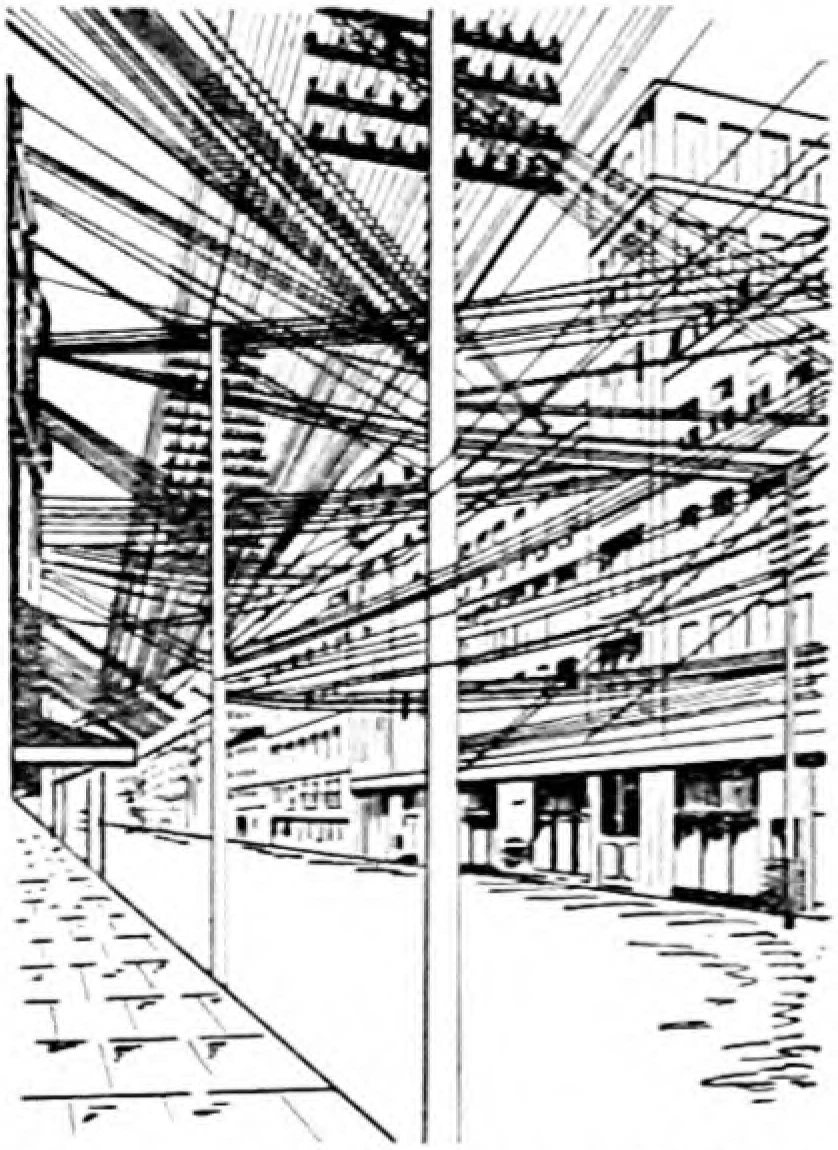


Fig. 178. Appearance of aerial circuits installed in a city street.

The first power cables were designed as two segment-shaped bare copper wires enclosed in a steel pipe filled with an insulating compound. This original, but rather primitive, construction naturally underwent a whole series of change.

The power cables that are in use today have impregnated-paper-insulated conductors and are enclosed in a continuous lead or aluminium sheath.

Electric power cables consist of three main elements: the current-carrying conductors, the insulation and the protective sheaths and coverings.

The conductors or cores serve to transmit the current to a required point and are made of copper and of aluminium.

As concerns the number of conductors or cores incorporated in them power cables are available with a single core, two cores, three cores and four cores.

Standard power cables have conductors with the following cross-sectional areas: 1.5, 2.5; 4; 6; 10; 16; 25; 35; 50; 70; 95; 120; 150; 185; 240; 300; 400; 500; 625; 800 and 1,000 sq mm.

Four-core power cables are manufactured for voltages up to 1,000 volts and are made so that three of their cores have the same size and the fourth core has a cross-sectional area about one half that of each of the other cores.

The insulating coverings in the cables serve to insulate the conductors from each other and from earth.

In power cables the fundamental insulating covering consists of impregnated paper, the impregnating compound being of special composition and consisting of high grades of rosin dissolved in a mineral oil.

The continuous, hermetic protective sheaths serving to preclude any penetration of moisture into the cable insulation are of lead or aluminium.

For protection against mechanical injury, cables may be designed with armour in the form of two steel tapes in one construction of cable, or round or flat wires in another.

Against chemical effect, lead sheaths are protected by servings of paper tape, jute or cable yarn impregnated with bitumen-base compounds.

2. Grades and Construction of Power Cables. Fields of Application and Methods of Laying. Packing

The construction of cables for voltages up to 10 kv and for 35 kv are shown in Figs 179 and 180. The grade designations of the most widely used power cables and the construction which they denote are listed in Table 17.

The application of different grades of power cables depends upon the construction of their insulation, protective sheaths and protective outer coverings. Thus, bare lead-sheathed cables should not be laid in places

Table 17

Power Cable Grade Designations and What They Denote

Grade designation	Kind of cable
СА (SA)	Lead-sheathed cable with paper-insulated copper conductors, protected by paper and jute coverings impregnated with asphalt-base compound
СБ (SB)	As above, but armoured with two steel tapes and provided with an outer covering of impregnated jute or cable yarn
СБГ (SBG)	The same as above, but without the outer covering
СП (SP)	The same as grade СБ (SB), armoured with flat steel wires
СК (SK)	The same as grade СП (SP), but armoured with round steel wires
АБ (AB)	The same as grade СБ (SB), but made with an aluminium sheath
ААБ (AAB)	The same as grade АБ (AB), but made with aluminium conductors
ОСБ (OSB)	The same as grade СБ (SB), but made with each conductor separately enclosed in its own lead sheath

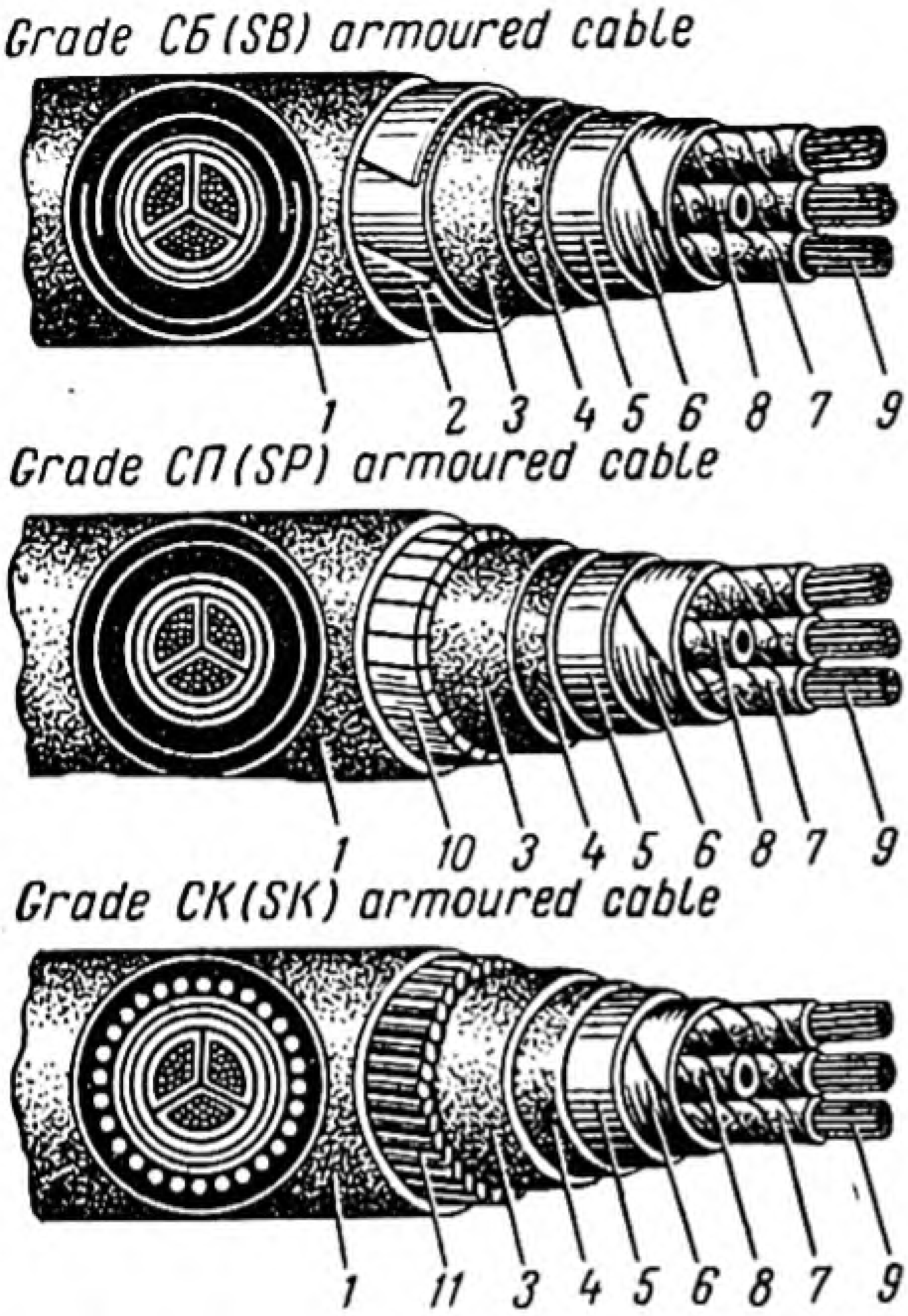


Fig. 179. 10-kv armoured cables:

1—covering of jute or cable yarn, 2—armour consisting of two steel tapes, 3—internal jute or cable yarn serving, 4—two servings of paper tape, 5—lead sheath, 6—belt insulation, 7—conductor insulation, 8—interstice fillers, 9—current-carrying conductors, 10—flat steel wire armour, 11—round steel wire armour.

where the chances for mechanical injury are large. Armoured cables without outer protective coverings of impregnated jute or cable yarn must not be installed where the armour will be subject to corrosion under the action of moisture present in the surrounding medium. Cables with tape armour must not be laid in places where their sheaths may be subjected to considerable tensile forces after the cables are put into service.

Depending upon their grade, cables may be laid and buried in earth trenches, run in duct blocks, tunnels, fixed to walls and ceilings, or run in covered cable trenches both inside and outside of buildings.

The fields of use of cables, according to the kind of installation and the character of the medium they are surrounded by, are given in Table 18.

Cables are shipped for laying reeled on cable drums (Fig. 181). Marked on the cheek of the cable drum are: the name of the manu-

Fig. 180. Grade ОСБ (OSB) armoured cable for 35 kv:

1—compacted round copper conductors with layer of semi-conductive paper over conductor, 2—oil-rosin-compound impregnated paper insulation with layer of semiconductive paper over insulation, 3—lead sheath, 4—interstice filling of cable yarn, 5—serving of cloth tape or cable yarn, 6—bitumen compound, impregnated cable yarn, bitumen compound with chalk coating, 7—steel tape armour.

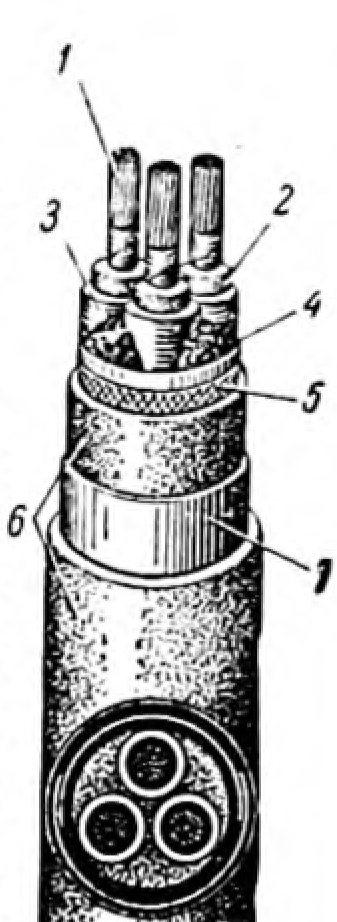


Fig. 181. Cable drum.

Table 18

Kinds of Cable Installations and Fields of Use of Different Grades of Power Cables

Kind of installation	Character of surrounding medium and conditions to which cables are subjected	Grades of cable used
Buried in earth trenches	Cable is not subjected to considerable tensional forces	СБ (SB), ОСБ (OSB), АБ(AB), ААБ (AAB)
	Cable may be subjected to considerable tensional forces	СП (SP)
Laid under water	Laid in crossings of unnavigable rivers, canals and lakes	СБ (SB), СП (SP)
	Laid in crossings of navigable rivers, canals and lakes	СК (SK), СП (SP)
Runs laid in cable channels, tunnels, over walls and ceilings, and over machine tools and mechanisms	In premises with a normal atmosphere	СБГ (SBG), СПГ (SPG)

facturing works, grade of the cable, number of its conductors, their size, the voltage for which the cable is rated, the length of the cable and the gross weight. The arrow painted on the cheek of the drum shows the direction in which it is permissible to roll the drum with the cable on it. The external end of the last outer turn on the drum is secured to the inside face of the drum cheek. The bottom end is brought out on the external side of the drum cheek where it is protected by a wooden box or sheet metal hood. Both ends of the cable must be reliably sealed with caps.

3. *Cable Laying in Earth Trenches*

Cable Route Preparation. Earth-trench-buried cable laying is the most widely used and economical method of cable laying. For cables with voltage ratings up to 10 kv inclusive, the depth of the earth trench must not be less than 700 mm. In deciding what depth to use, it is necessary to take into consideration any possibility of changes being made in the existing grade level by any earth cut or fill work to be carried out later in the course of construction.

The width of a trench dug for one cable should equal 250 mm (the width of a shovel).

When a larger number of cables must be laid, the width of the trench must be such that a free space of 100 mm remains between any two neighbouring cables and that the free space left between the extreme cables and the trench walls is not less than 50 mm (Fig. 182).

At the turns in the cable route the trench should be dug with a radius not less than 15

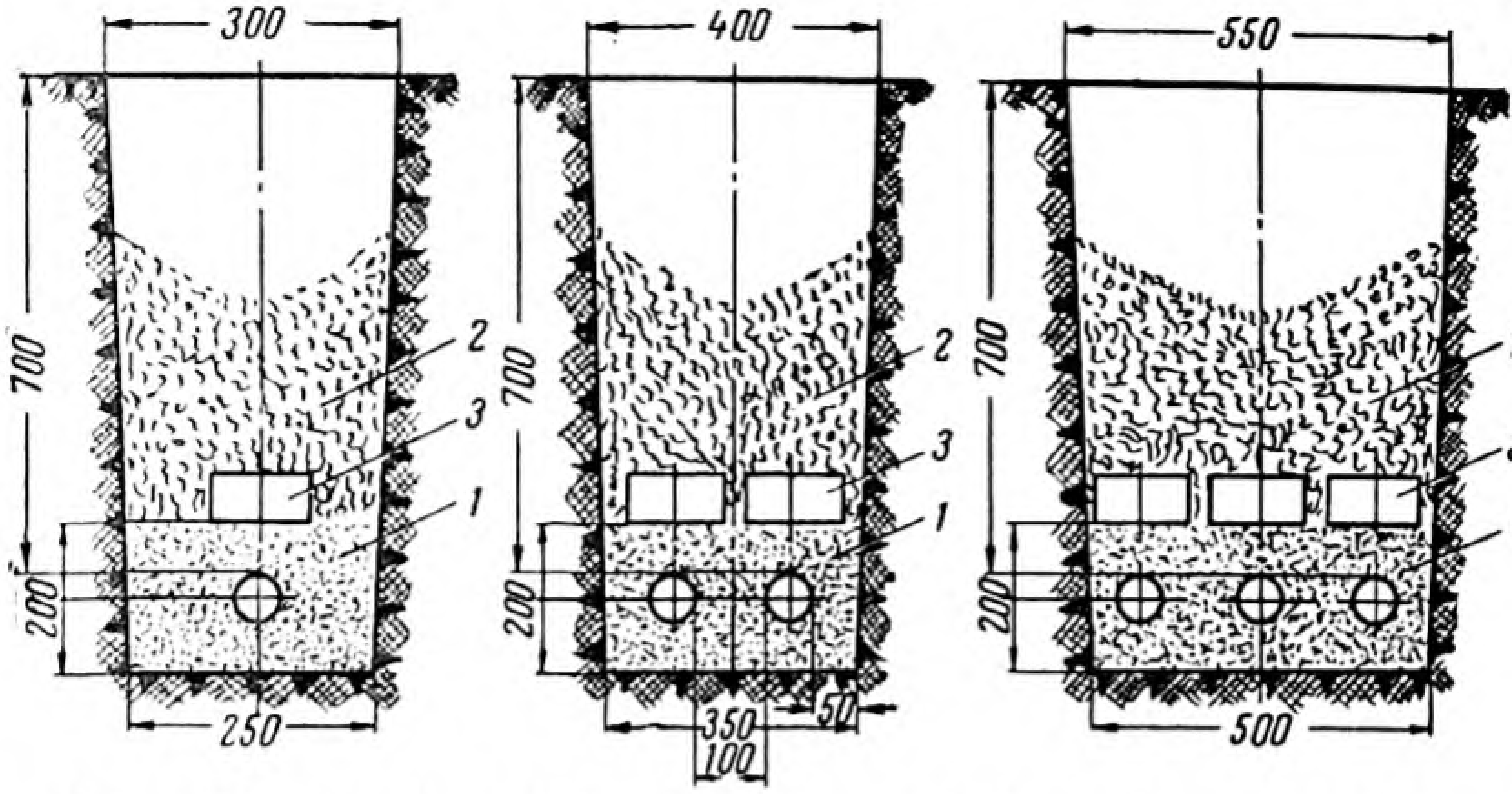


Fig. 182. Cable trenches, their dimensions and the arrangement of the cables in them:

1—bedding layer of soft screened soil or of sand, 2—backfill earth, 3—bricks.

cable diameters for three-core cables and 25 cable diameters for single-core cables.

For jointing one cable rated for a voltage up to 10 kv, a pit 1.5 m wide by 2.5 m long should be dug. For every additional cable jointing box laid in alongside, the width of the pit must be increased by 350 mm. To be borne in mind is that the jointing boxes are to be staggered along the route line by at least 2 metres from each other.

Trenches are usually dug by hand when they are short in length or routed under footways with asphalt-concrete coverings. In the latter case, and when frozen and dense soils have to be dealt with, it is advisable to use pneumatic paving breakers.

Where the cable route intersects roads, streets, thoroughfares, etc., steel or asbestos-cement pipes are laid in the trenches to serve as ducts for the cables. In such cases the steel pipes are jointed by arc welding or steel clamps, and the asbestos-cement pipes are jointed with asbestos-cement couplings.

After a trench has been dug, the soil at the bottom must be loosened to create a soft bedding up to 100 mm deep. All stones and construction debris should be removed from this bedding layer. Such a bedding can also be made by putting in a 100-mm layer of sand or soft screened soil.

Loading and Transporting of Cable Drums. Cables when reeled on their drums may be transported on motor trucks, upon which they are loaded by a crane or a loading winch. As a rule, the drums must be lashed to the truck body with wire ropes and wedged with four wedges (Fig. 183). If this is not done, the drums may begin to roll during transportation and damage the driver's cab.

A much more convenient way to load, transport and unload

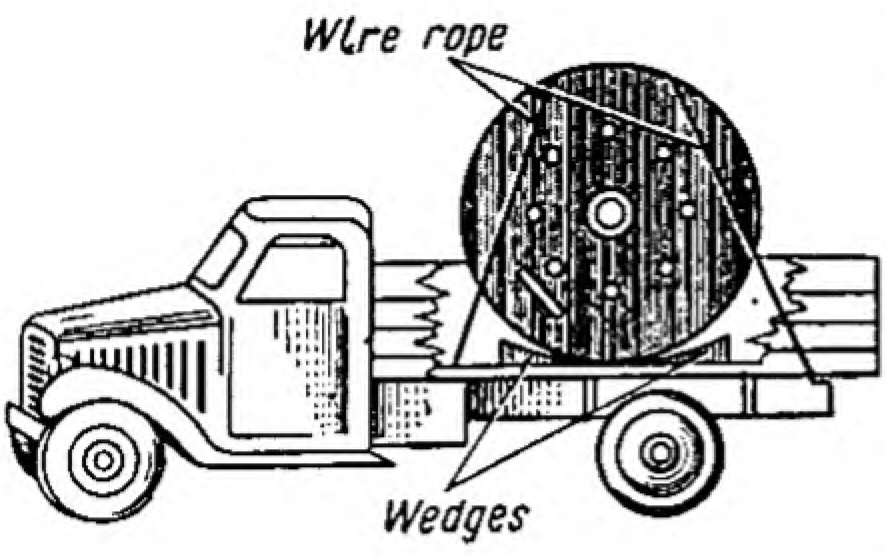


Fig. 183. Transporting a drum of cable on a motor truck.

the drum can be rolled by hand in the direction indicated by the arrow painted on the drum. If a drum is rolled by mistake in the opposite direction, the turns of the cable will become loosened and tangled with each other, and the cable may be injured. As the drum is being rolled, all objects such as stones, pieces of wood, steel, etc., which may break the lagging,

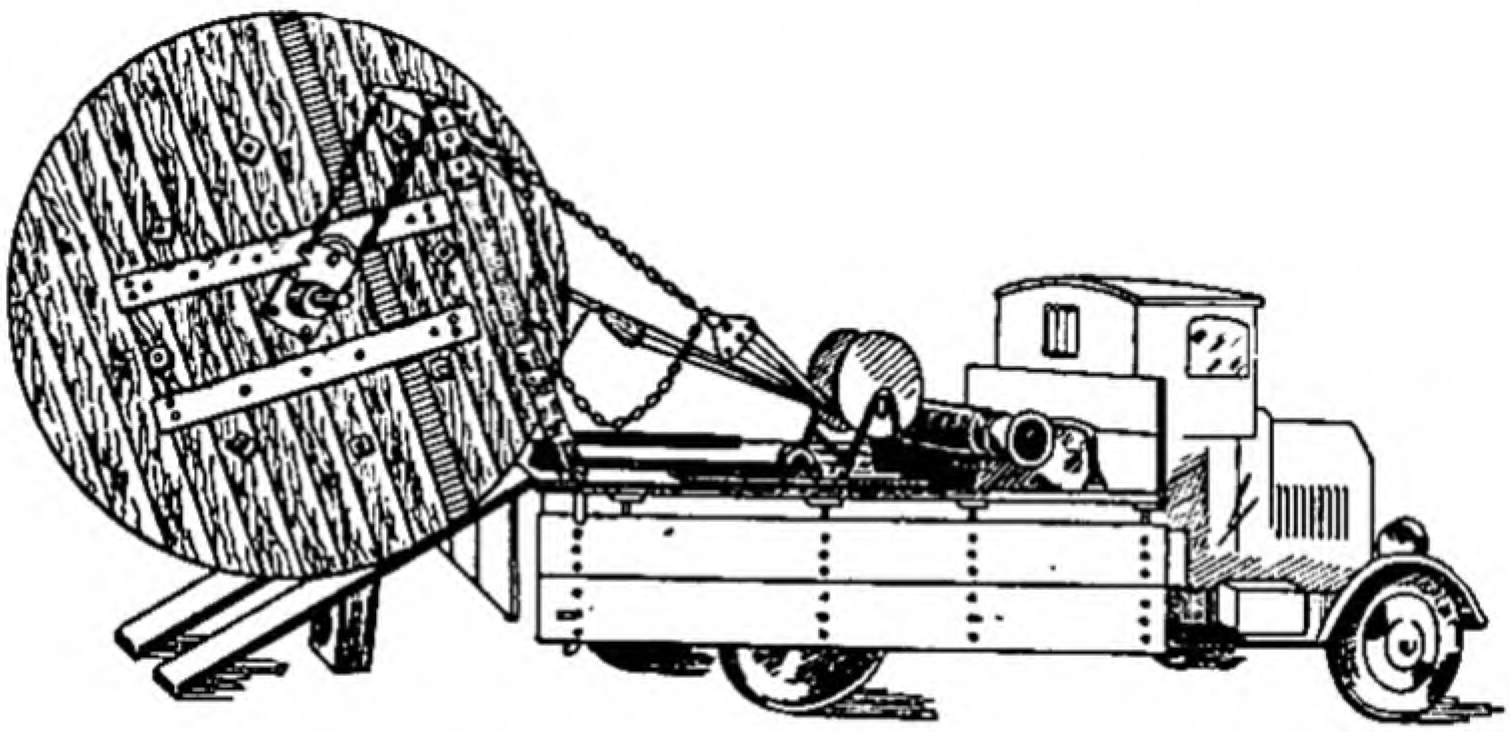


Fig. 184. Model ПКБ-3 (PKB-3) cable drum loader.

cable drums is to use motor trucks equipped with a special ПКБ-3 (PKB-3) cable drum loader (Fig. 184).

A still more modern means for loading and unloading drums of cable is the special TK-5 cable drum transporting trailer (Fig. 185). The number index of the model designation indicates that the trailer has a carrying capacity of 5 metric tons.

Special trailer trucks and autoloaders are also frequently used to transport drums of cable.

When the distance over which a cable drum is to be moved is small (up to 20 metres), and if the path is smooth and level,

should be removed from the path of the drum. If the soil is

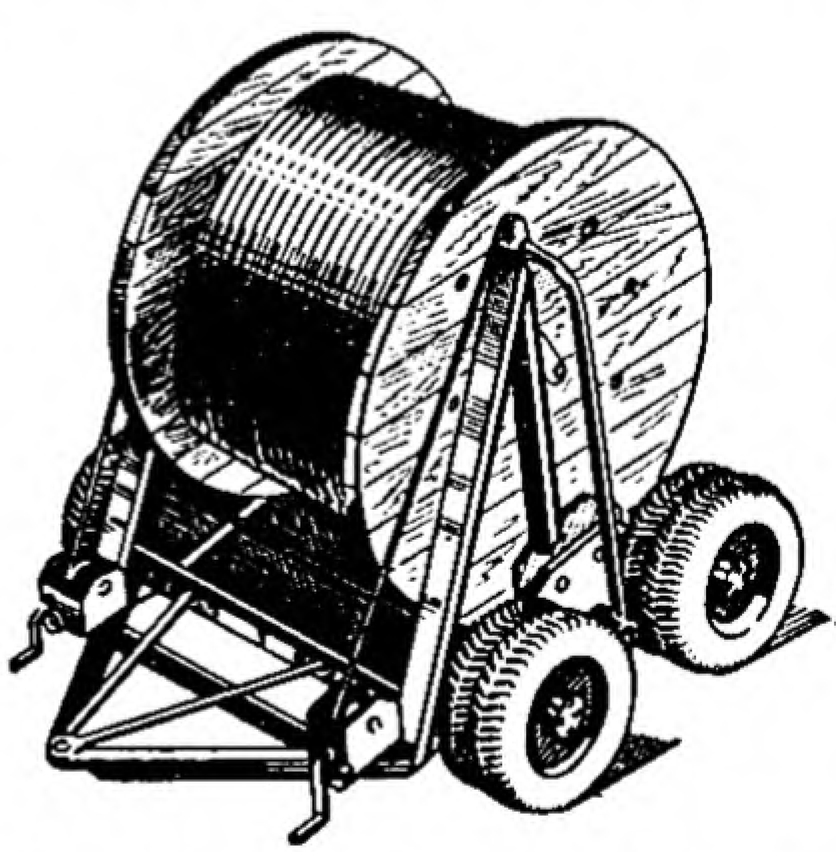


Fig. 185. Model TK-5 cable drum transporting trailer.

soft, the drums should be rolled on planks laid over the path to be travelled. Over boggy routes and also under slushy and muddy conditions drums of cable may be moved by placing them on a sheet of plate steel 6 to 10 mm thick and towing the latter with a tractor or motor truck.

Cables must be transported on drums which are in a fit condition because cables transported on bad drums may be injured during transportation. It is for this reason that drums of cable prior to transportation require a thorough external inspection during which the drums are specially checked for adequate strength and for intactness of the boxings used to protect the ends of the cables brought out through the sides of the drums. When drums are found to be damaged, they must be repaired in order to be fit for transportation.

In individual cases short lengths of cables (up to 25 metres) can be transported without being reeled on a drum. In such cases the cables are laid in coiled form, each coil of cable being securely tied together at not less than four places round the coil.

To avoid highly probable injury to the cable, never hurl down or roll drums of cable off a truck. It is best to unload a drum directly at the point where the cable is to be unreeled from the drum. At the same time, when on the territory of an industrial works, it is necessary to unload the drum where inter-shop traffic will not be interfered with.

If immediate installation of the cables is not contemplated, the drums of cable are to be gathered at one place where they may be stored outdoors for a period of up to one year. During storage the cheeks of the drums should rest on wooden planks. When the drums of cable are to be stored for a longer period of time, a shelter roof should be built over them.

Unreeling of Cable Along Cable Route. Cable drums held in a TK-5 transporting trailer or a ПКБ-3 (PKB-3) cable drum loader are turned by hand to unreel the cable. Workers moving behind the truck or trailer take up the cable as it is paid off and lay it in the bottom of the trench. Unreeling of the cable should be done so that the cable is paid off from the top of the drum and not from the bottom.

The trailer or loader should be moved at a speed of 3 km per hour at a distance from the edge of the trench to the trailer or loader kept equal to at least the depth of the trench in all kinds of soils, with the exception of sandy loam for which the distance should equal trench depth multiplied by the factor 1.2.

Cables may also be unreeled over rollers by drawing them off their drums with a motor-driven or hand-operated winch, or by hand.

For unreeling, the drums are raised so they can turn on a steel axle supported by cable drum jacks (Fig. 186). The steel axle is passed through the centre

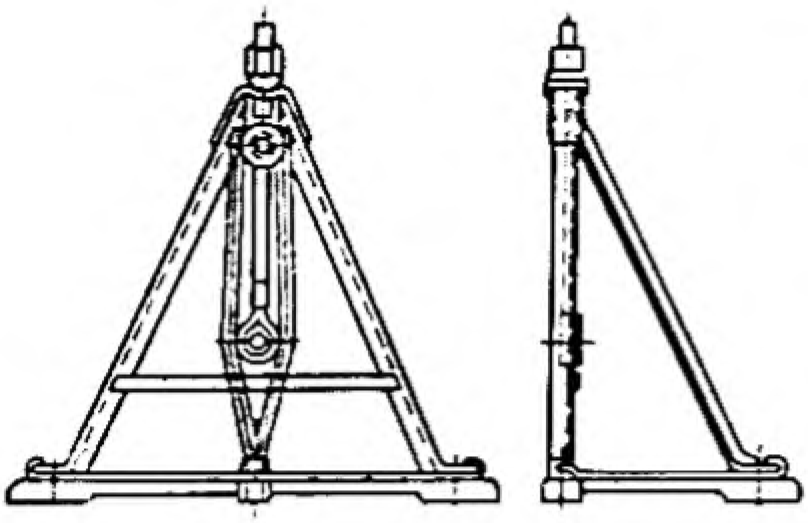


Fig. 186. Cable drum jack.

of the drum and its diameter should be selected in accordance with the gross weight of the drum.

Weight of drum, kg	Diameter of axle, mm
Up to 2,500	60
Up to 3,500	70
Up to 5,000	75

Before a cable is unreeled, the straight-line and turn rollers mentioned above are to be laid out along the cable route at distances of 2.5 to 3 metres from each other. How the straight-line rollers at straight sections and the turn rollers at a turn in direction are laid out is shown in Fig. 187.

When cable pulling is done with a winch, hand or power operated, the winch is placed at one end of the route section and the drum of cable is placed at the other end. The wire pulling rope can then be paid off the winch drum and attached to the end of the cable with a cable-pulling stocking. The latter is slipped over the lead-sheathed end as illustrated in Fig. 188*a*. Instead of a cable-pulling stocking, a special type of pulling clamp can be used (Fig. 188*b*).

In cases when the length of cable to be pulled is large, good practice is to additionally attach the cable to the pull rope with steel clips as the paid-out cable length becomes greater and greater.

Cables are also laid manually. During this work the cable-laying men carry the cable on their shoulders and pull it out along the cable trench, walking along the edge of the trench, or down the bottom of the trench

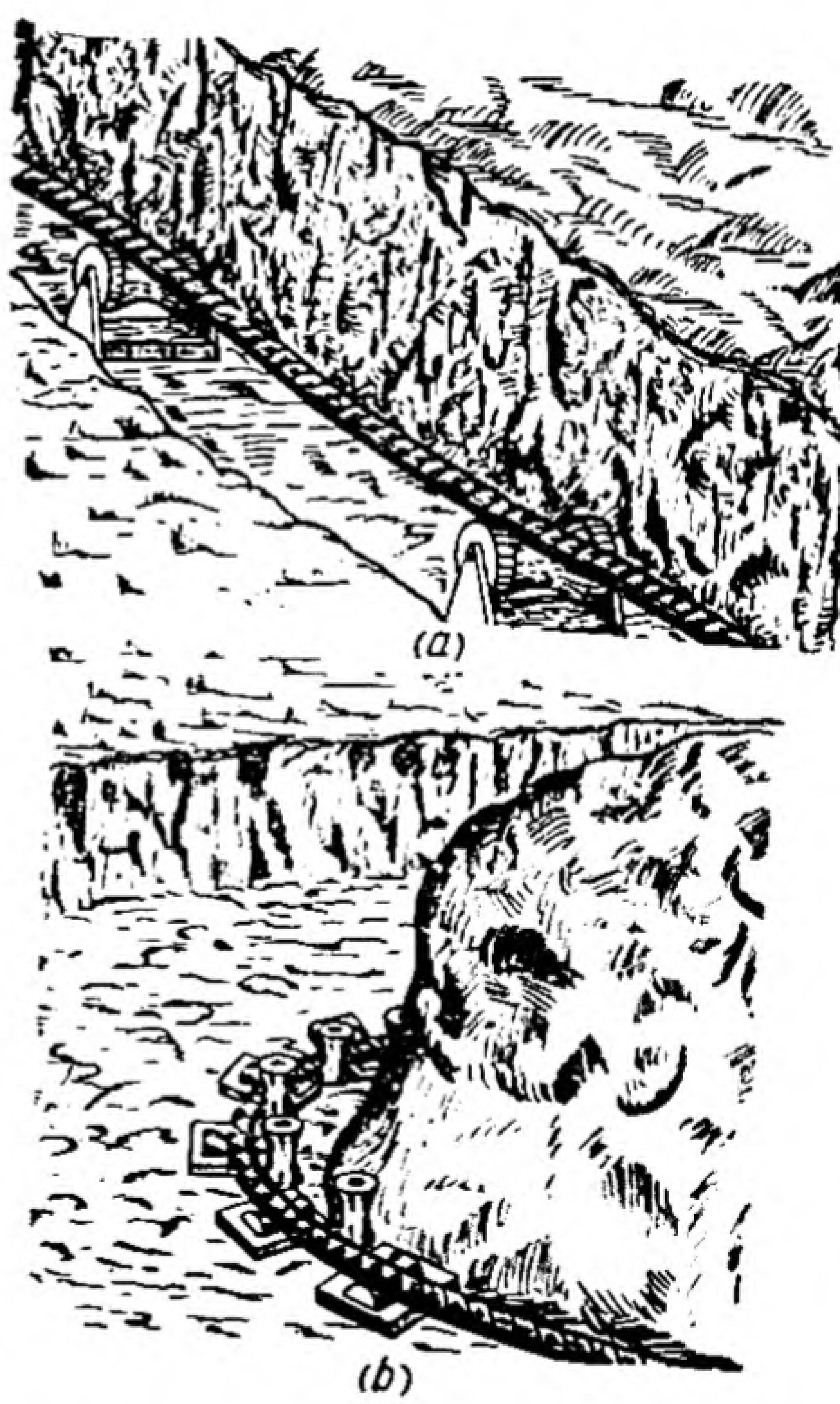


Fig. 187. Rollers used in unreeling cables along a route:
a—straight-line rollers, *b*—turn rollers.

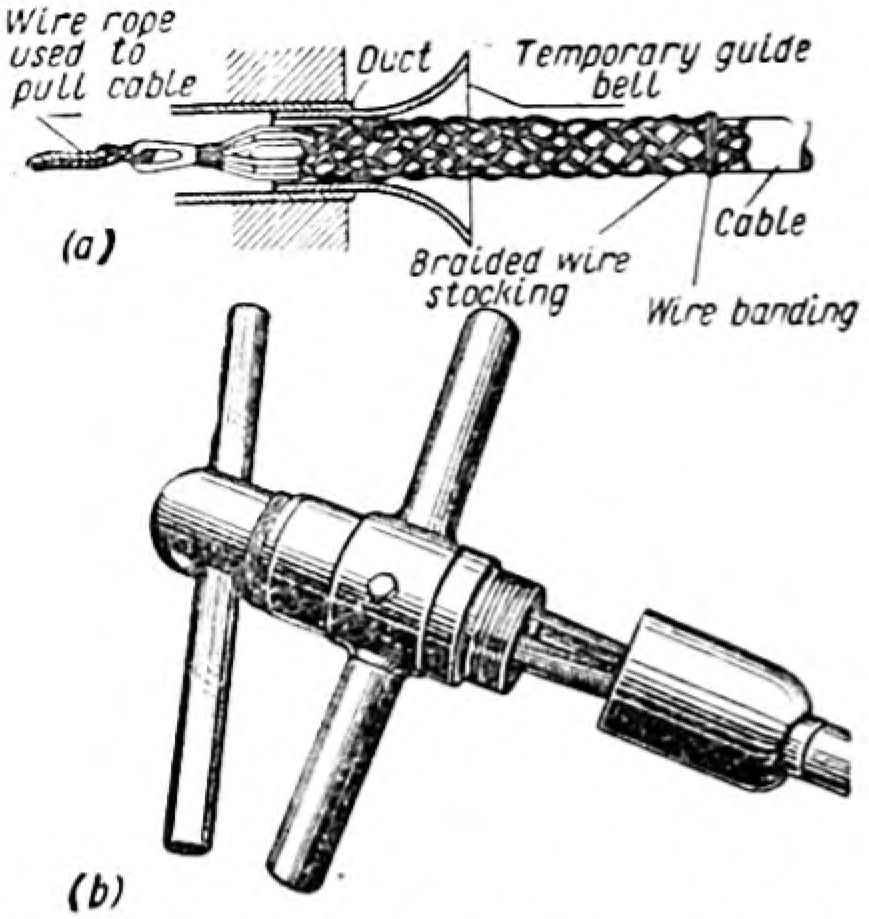


Fig. 188. Attaching wire rope to cable for pulling:
a—with a braided wire stocking, b—with a clamping device.

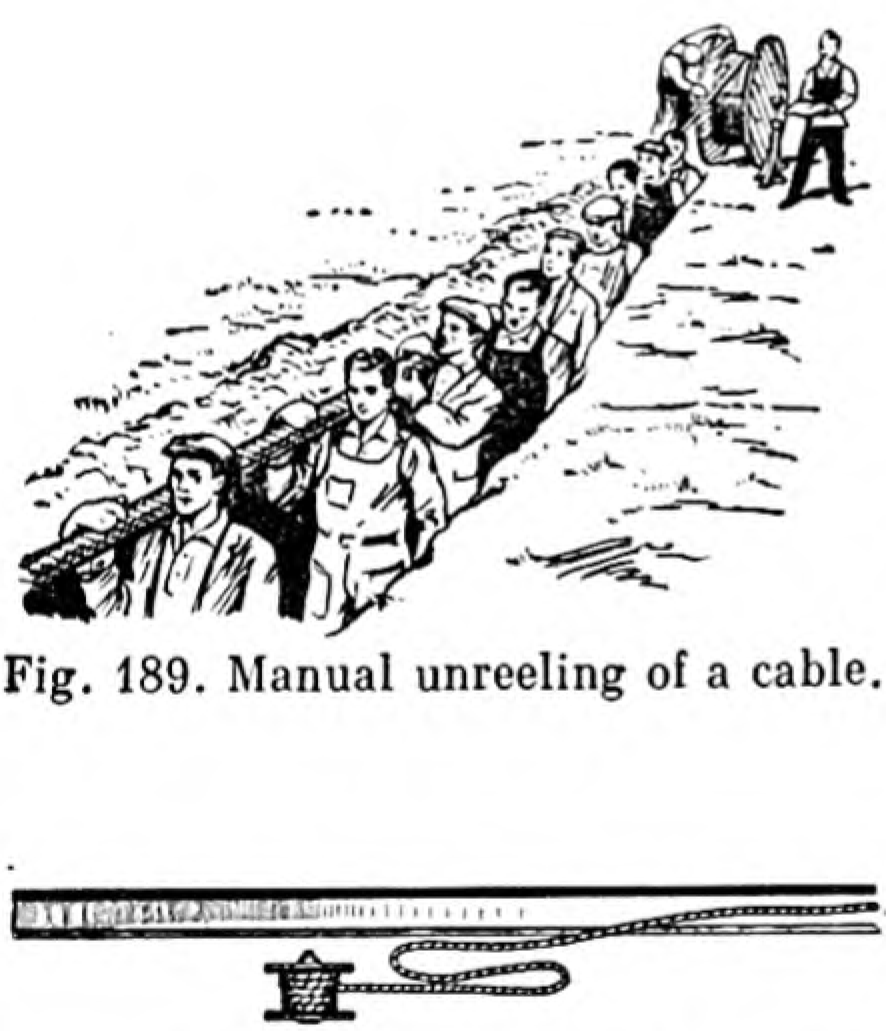


Fig. 189. Manual unreeling of a cable.

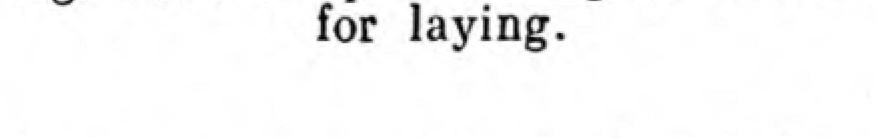


Fig. 190. Loop unreeling of a cable for laying.

(when it is sufficiently wide—Fig. 189).

If the team is too small to work as above, the cable can be laid out in loop form and each loop of unreeled cable then laid in the trench (Fig. 190).

During hand pulling and laying of cables always bear in mind that the weight to be borne by an adult worker should not exceed 35 kg; that of a boy helper must not exceed 25 kg.

Cables when carried on the shoulders must not be allowed to sag with sharp bends and must be lowered from the shoulders with care. Never should the cable be dropped. The cable should be carried by each man on the same shoulder in order to avoid injury when the cable is lowered in place.

In all cases of laying the cable is to be laid in so that it forms a slightly wavy line in order that its length will be from 0.5 to 1 per cent greater than true route length. This length margin is necessary to avoid longitudinal stresses being developed in the cable as a result of possible subsequent settling of the soil or switch-off of the load in the cable during the frosty season when the total length of the cable decreases because of contraction.

Where joints are to be made, the ends of the cables should overlap by about 1.5 to 2 metres. This overlap provides the necessary excess length for cable dressing in making up the joint and fitting the joint box and also provides for loose looping of the cable on both sides of the joint box to prevent any development of mechanical stresses at the entrance throats.

Where new cables intersect with previously installed cables and other underground services, they should be installed

in accordance with the dimensions prescribed in Fig. 191.

Cable Tagging and Route Marking, Cable Testing and Trench Backfilling. After a cable has been laid out on the bottom of the trench, identification tags are tied to it at intervals of 20 metres on straight sections, at entrances into pipe ducts and at entrances into buildings. The tags are prepared of sheet metal protected with a corrosion-proof coating. On them are to be stamped: the cable voltage rating, grade designation, the size of the cable conductors, number of the feeder or name of object supplied, name and initials of person responsible for the installed cable and the date of installation.

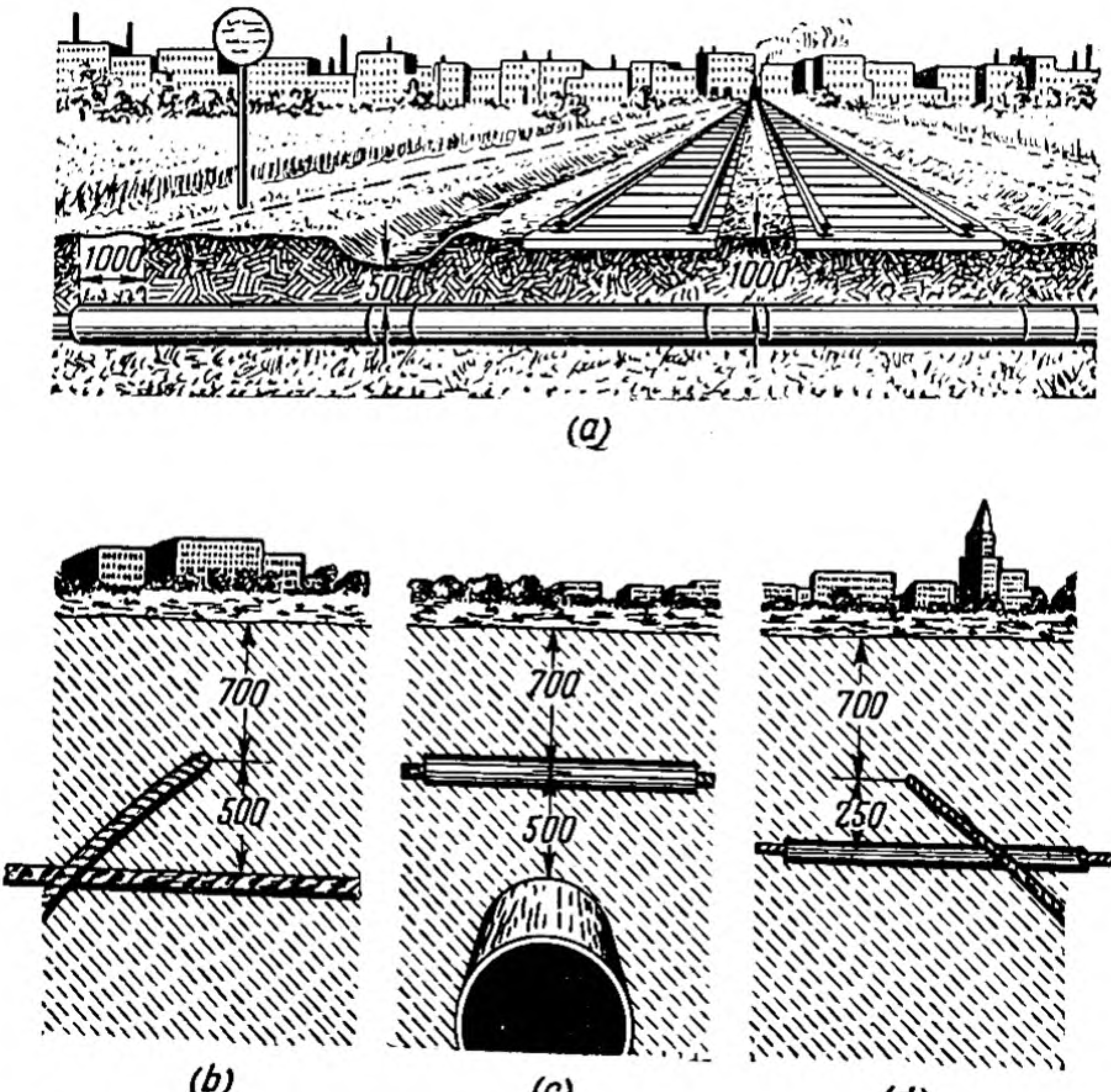


Fig. 191. Distances of intersection of cables with other cables and with other underground services:

a—intersection of a power cable with a railway line, *b*—intersection of one cable with another cable, both being buried in earth, *c*—intersection of a power cable with a pipeline, *d*—intersection of one cable with another cable laid in a pipe.

Before the trench of a cable route can be backfilled, the route is inspected and an inspection report is drawn up and signed. An "as-installed" sketch or drawing of the route is also made to show the distance of the cables and the cable joint boxes from surrounding permanent structures. The inspection is conducted by the installation job supervisor and a representative of the organisation which is to operate the cable lines.

After inspection, the cables are measured for their insulation resistances with a 500 or 1,000 v megger and subjected to a withstand-voltage test with a rectified voltage equal to six times rated voltage of the cable. This voltage is obtained from a kenotron-rectifier testing set (see Chapter XIII, "Operation and Maintenance of Electric Circuits and Equipment").

Testing completed, the cable route is marked off with signs in the form of identification marks attached to or painted on the walls of permanent nearby buildings or structures, or with angle-iron sign posts. The signs are put in at intervals of 100 metres on straight route sections, at turns in direction of the cable route, at places where joint boxes have been installed and at intersections with transportation facilities (at both sides).

After the cable route has been marked off, the trench can be backfilled. The first layer of the backfill should be 100 mm thick. A row or rows of brick or concrete plates are then laid on top of the first layer of earth. Final backfilling of the trench, after this, should be done in several steps, each new layer of earth being tamped down or laid in so as to create a dense backfill of the earth. This fosters better cooling of the buried cables. For better settling of the soil, it is advisable to wet each layer of earth with water. When the amount of earth to be backfilled is small, the work can be done by hand. Bulldozers should be used to backfill trenches and do the clean-up work when the volumes of earth to be moved are large.

Cable Laying in Duct Blocks and in Tunnels. In large cities and in industrial undertakings having large territories, widely practised is laying of cables in cable ducts assembled of two-metre long single-duct or multi-duct concrete conduit.

This type of conduit is installed in trenches with manhole pits provided at intervals of 70 to 100 metres for pulling in and making the necessary joints in the cables.

Cost estimates show that the installation of cables in ducts is economically justifiable when the number of cables run parallel to each other does not reach 40. When the number of cables exceeds this figure, it is not expedient to install the cables in tunnels.

Cable tunnels take the form of an underground gallery constructed of reinforced concrete, or rarely, of brick. In such tunnels the cables are secured on special attachable supports, or on metalwork supports fabricated

from angle iron, hot-rolled steel wire, etc.

In several kinds of electrical installations the tunnels are provided with special cable racks which form part of the tunnel wall and are built in during construction of the tunnel.

Cable Laying in Frosty Weather. If the temperature of the air during a period of 25 hours prior to the time a cable is to be laid drops below 0°C only for a short interval of time, the cable must be heated before it can be laid.

To heat a drum of cable the circumferential sheathing planks are removed. Cables may be warmed in heated rooms or in specially made heating sheds. In the latter case the necessary temperature is attained with the aid of hot-air blower unit.

Duration of Cable Heating Period

Air temperature in room or heating shed, °C	Duration of heating, hr
From + 5 to + 10	72
From + 10 to + 25	24 to 36
From + 25 to + 40	18

The duration of the heating period for a cable placed in a heated room, or a heating shed depends upon the ambient air temperature.

The drum of cable should be turned on its axis from time to time through one half a revolution for uniform warming. The ambient air temperature is measured with a mercury-bulb thermometer. When the cable is heated in a heating shed, a fire extinguisher and a box of sand must be kept on hand as a measure of fire protection.

Also practised by installers is the heating of cables with electric current (Fig. 192). This method provides a uniform rise in temperature in all of the turns of the cable within relatively short periods of time.

To heat cables with electric current, the top ends of the cables are dressed and fitted with temporary sheet-metal sealing bells and connected into a circuit as illustrated in Fig. 192. The inner cable end brought out on the cheek of the last drum (not shown in Fig. 192) is also terminated by dressing it down to the conductors and shorting them to each other. Supply for heating is taken from an autotransformer.

Data on the currents, voltages and warming times used in cable heating can be seen in Table 19.

Table 19

Cable Heating Data

Size of cable conductor, sq mm	Maximum heating current, amp	Volts required per 100 metres of cable	Approximate heating time (in min) with three-phase current at ambient air temperature: −10° C	−20° C
10	76	23.0	76	97
16	102	19.0	73	97
25	130	16.0	88	106
35	160	14.0	93	112
50	190	11.5	112	134
70	230	10.0	122	149
95	285	9.0	124	151
120	330	8.5	138	170
150	375	7.5	150	185
185	425	6.0	167	208
240	490	5.3	190	234

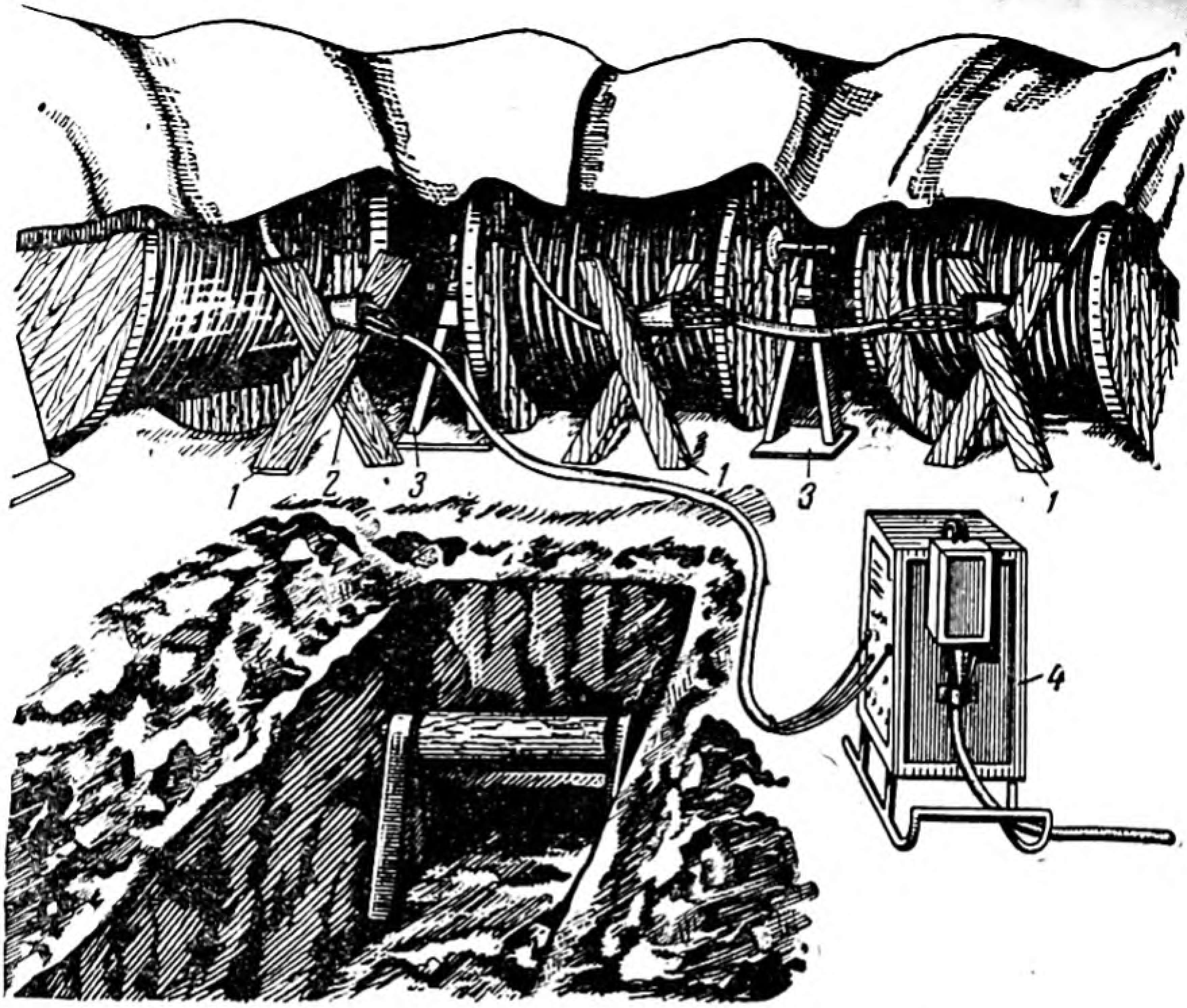


Fig. 192. Cable heating with electric current:
1—crossed-board support, 2—temporary end bell, 3—cable drum jack, 4—autotransformer.

Task. Draw up an operation-sequence card for laying power cables in earth trenches.

4. Cable Installation in Buildings

Preparation of Cable Route. Open-installed cable lines within buildings are laid out and marked off on the walls and ceilings by using a marking cord and plumb line. Since the cable is mounted exposed, the lines should be laid out in conformance with the general architectural and structural lines of the building.

The support metalwork parts for the cables are either grouted in with cement mortar or are welded to built-in metal anchor parts put in during construction of the walls and ceilings in the building.

Today a large proportion of the cable support metalwork is fixed to mounting surfaces with a powder-actuated СМП-1 (SMP-1) stud driver. Different forms of support metalwork for cables are shown in Fig. 193.

Cables are protected by steel pipes when passed through walls and floor structures in buildings. The latter are cemented into the holes before the cables are

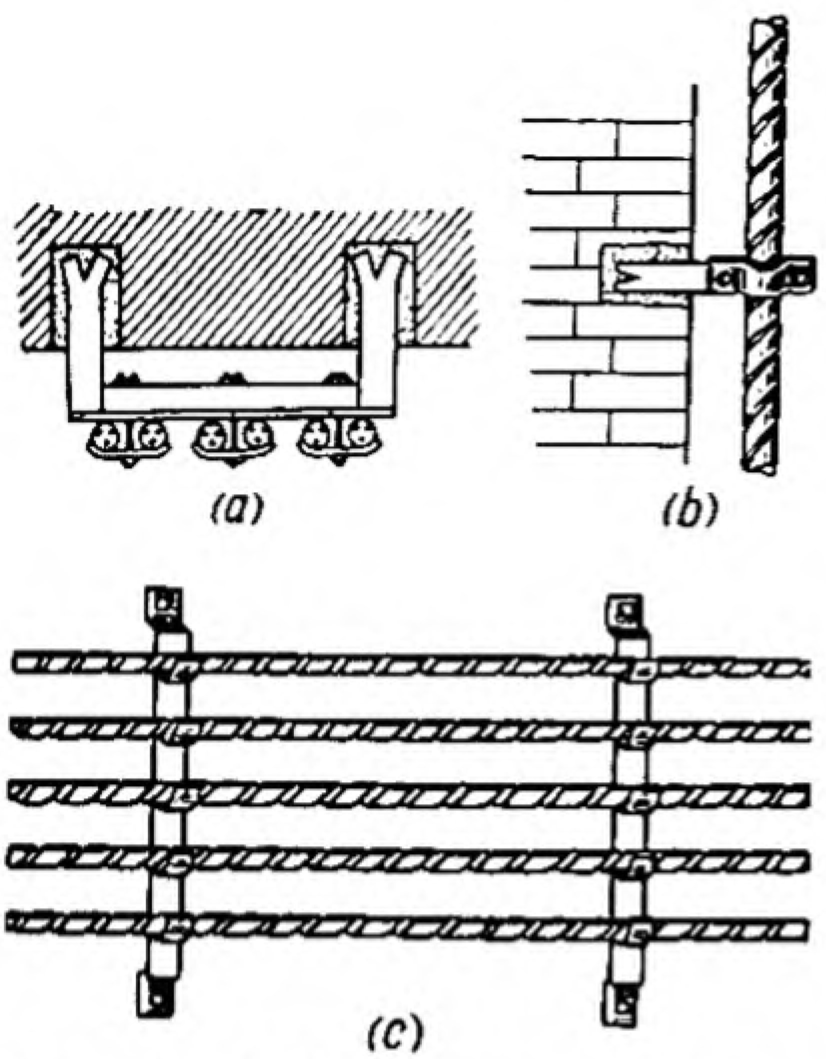


Fig. 193. Cable support metalwork:
a—stirrup fixed in ceiling with cement mortar, b—clamp fixed in a wall with cement mortar, c—support metalwork fixed by means of a type СМП-1 (SMP-1) powder-actuated stud driver.

pulled through. The pipe used to pass the cable through a floor structure is made long enough to end at least 2 metres above floor level to guard the cable from possible injury.

Installation of the Cables. In putting in sections of relatively great length, the cables are paid out on to unreeling rollers spaced at 5-metre intervals.

Unreeling is done by hand with the cable carried in the hands and not pulled. The weight of cable to be taken by each cable layer or his helper must not exceed the weight limits stated earlier (35 kg and 25 kg).

In installing the cable it must first of all be pulled through all the passages.

Split wide-mouthed pulling bells inserted in the pipe end are used to avoid hand injuries during pulling of a cable through a wall or other hole. The cable, on being laid out along its route, is then placed on its supports, its slackness removed and the cable as a whole straightened out.

At the various sections along its route the cable can be smoothed out with a wooden mallet or a 400 to 600 gram hammer, a block of wood being placed on the cable for striking with the hammer.

When cables are installed in buildings, they may be laid in floor trenches in which the cables can be placed directly on the bottom of the trench, or on support hooks or brackets fixed to the trench walls (Fig. 194).

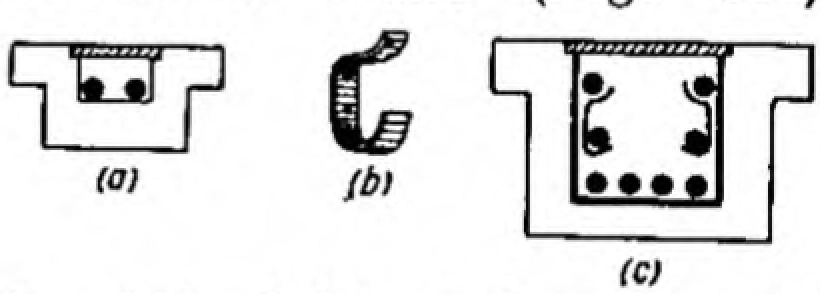


Fig. 194. Cable laying in floor trenches:
a—two cables laid on the bottom of a floor trench, b—hook bracket for supporting cables on trench walls, c—cables laid on the bottom and supported on the walls of a floor trench.

Where long vertical runs or a large number of cables must be put in, mechanical means should be used to do the unreeling, one of such means being an endless rope arrangement with a power drive (Fig. 195). This kind of arrangement is suitable for raising cables from a lower to a higher level and also for lowering them from a higher to a lower level.

After a cable has been unreeled and pulled through all the

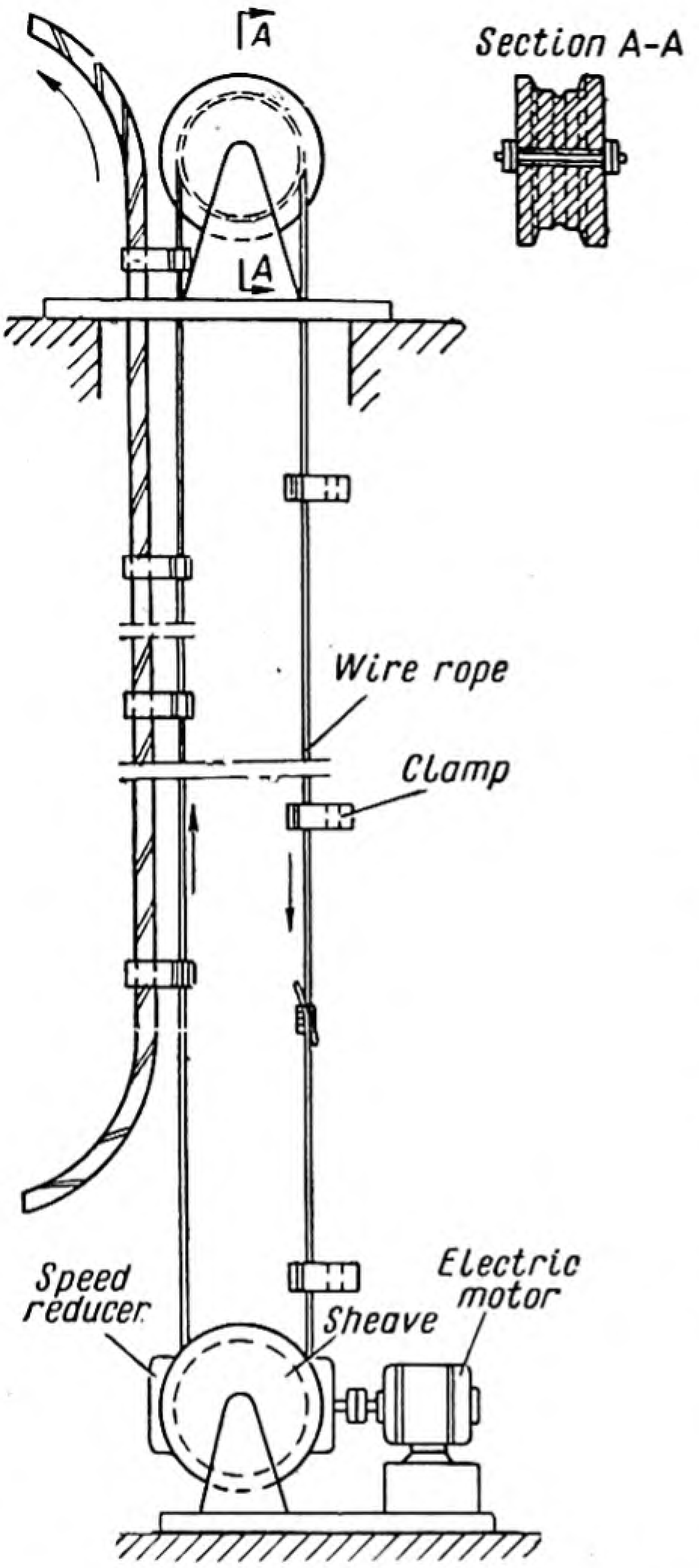


Fig. 195. Endless rope arrangement for installing cables on vertical runs.

hole passages over a given route section, it is laid on the supports and secured. Where the cable is run over a vertical stretch it is fixed at each support provided over the section without exception, but where the route becomes horizontal it may be rigidly fixed only at end points, at places where a turn is made and at joint boxes and sealing bells.

Armoured cables provided with a fibrous protective covering must have the covering removed when they enter buildings to avoid a fire hazard.

After the cables are in place and their fixing has been completed, they require inspection and testing by the same methods employed with cables buried in earth.

The final operation is to tag the cables. Metal identification tags are tied to the cables at 20-metre intervals over straight sections, at all turns in the route, at each entrance and exit of a cable into and out of a wall or floor structure opening and also at the joint and sealing boxes. The tags are tied to the cables with soft binding wire.

For protection of the cable armour from corrosion, all cables installed within buildings must have a coating of protective paint or varnish applied to them after installation.

Task. Draw up the sequence of operations followed in laying cables in floor trenches.

5. Cable Dressing for Jointing and Termination and Cable Sheath Earthing

General. When cables are dressed for jointing or termination, the air- and moisture-tightness of their lead or aluminium sheaths is disturbed. This circumstance creates a possibility for loss in dielectric strength of the

cable insulation and even an eventual breakdown of the insulation.

Notwithstanding the above circumstance, the more skilfully and better the dressing of cable ends is performed, the greater the reliability of the cables in service.

This is why it is of extreme importance to follow the corresponding cable jointing and terminating instructions very thoroughly and carefully.

To prevent moisture, dirt, etc., from getting into the cable when making a termination or joint, the jointer must take special care to keep his hands, the cable sleeve, the joint box, the dressed ends and his tools spotlessly clean.

To joint or terminate a cable, the jointer should have his tools fully prepared for the work, should wipe them clean, lay them out in the order they are required, and cover them with a piece of tarpaulin or oilcloth to protect them against moisture and dust.

Once the splicing and boxing of a cable is commenced, it must be continued to completion without any interruption, all the work being done by one team (the jointer and his helper).

Cable Dressing. The first step is to apply a banding over the cable armour (considering in this case that we are jointing a grade СБГ (SBG) bare, tape-armoured, lead-sheathed cable). This is done at the necessary distance from the cable end. The banding is applied with soft binding wire of 0.8 to 1 mm diameter wound in 5 to 6 rows over a previously applied serving of 2 to 3 layers of tarred tape (Fig. 196*a*).

Using an armour cutter, the armour tape is next cut through and the armour removed (Fig. 196*b*). The latter is first untwisted to loosen it and is then pulled off (Fig. 196*c*).

After the armour has been removed, the internal serving of jute is unwound and trimmed off (Fig. 196*d*), holding the cutting edge of the trimming knife faced in the direction of the armour to avoid damaging the lead sheath if the knife slips.

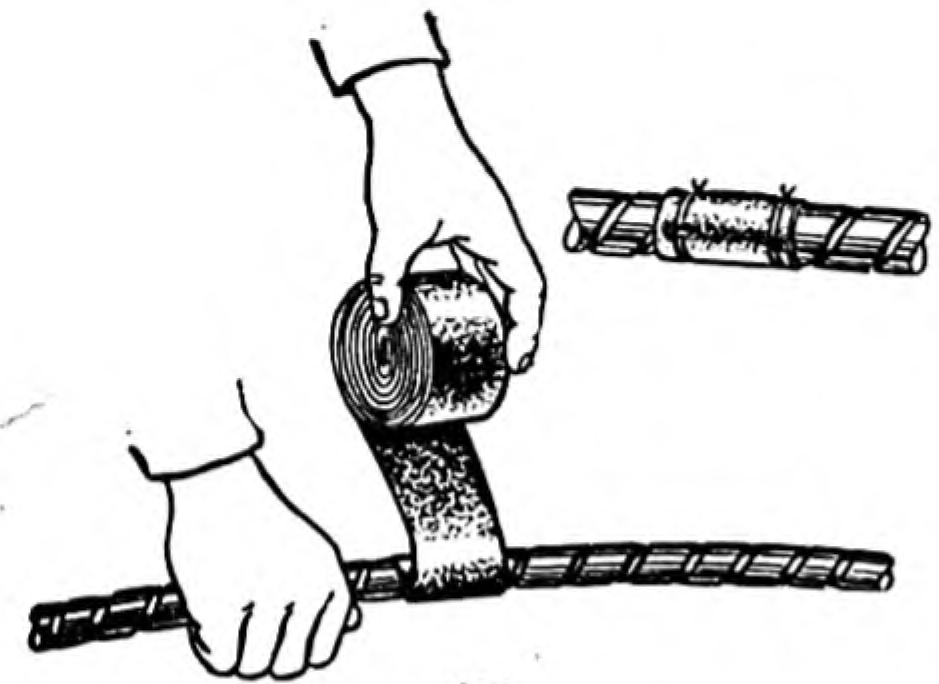
After warming (Fig. 196*e*), the layer of cable paper wound over the lead sheath can be removed.

The next steps are to thoroughly clean the lead sheath with a rag wetted in petrol and make circular notches in the lead sheath at distances S and T (Fig. 196*f*) from the trimmed edge of the armour.

The circular notches should be cut to about one half the thickness of the lead sheath.

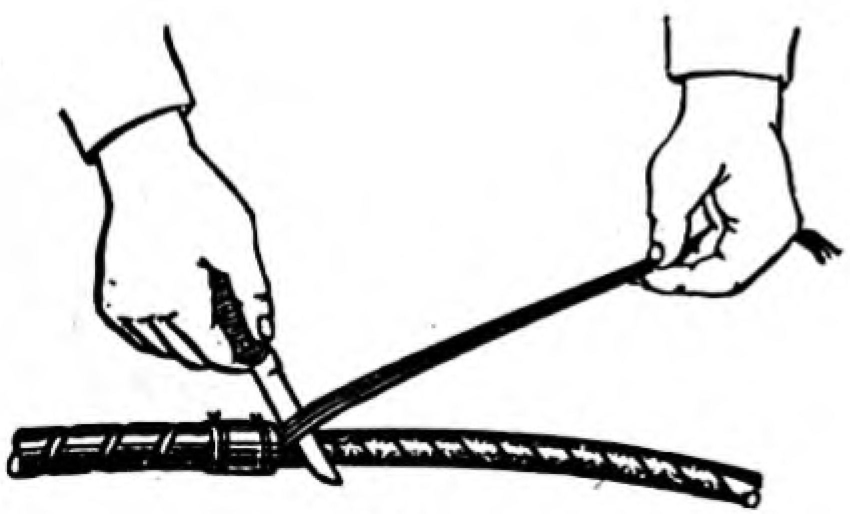
Next, beginning from the second circular notch (nearest the edge of the banding on the armour), and up to the end of the cable, two longitudinal cuts are made at 10 to 15 mm from each other in the sheath with a knife or lead-sheath cutting tool (Fig. 196*g*). The latter is convenient to use because it does not fully cut through and makes two strictly parallel cuts.

Before the undercut part of the lead sheath is removed, a


(a)


(b)


(c)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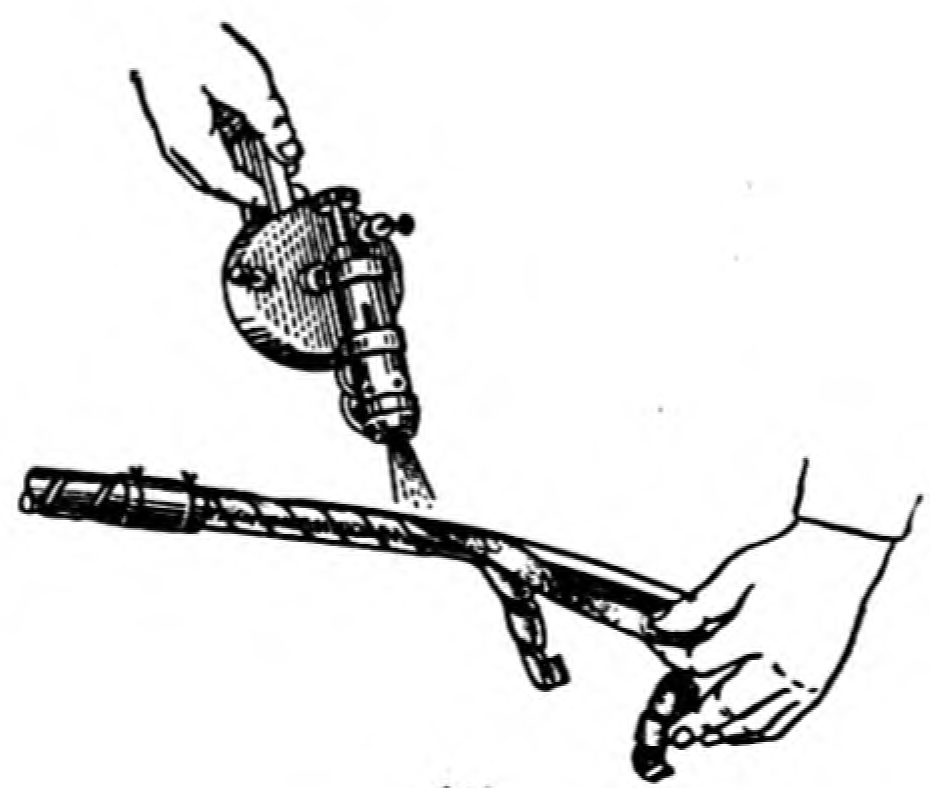
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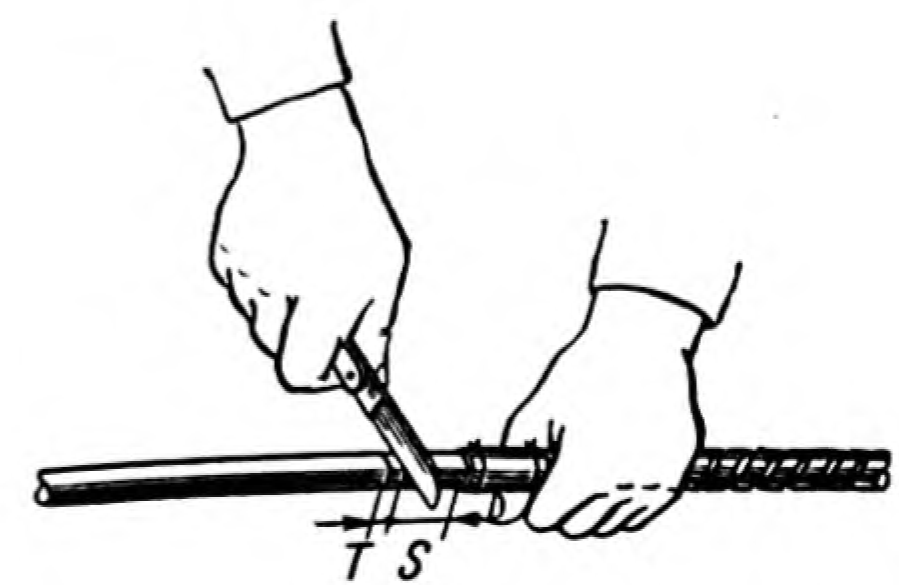

(f)

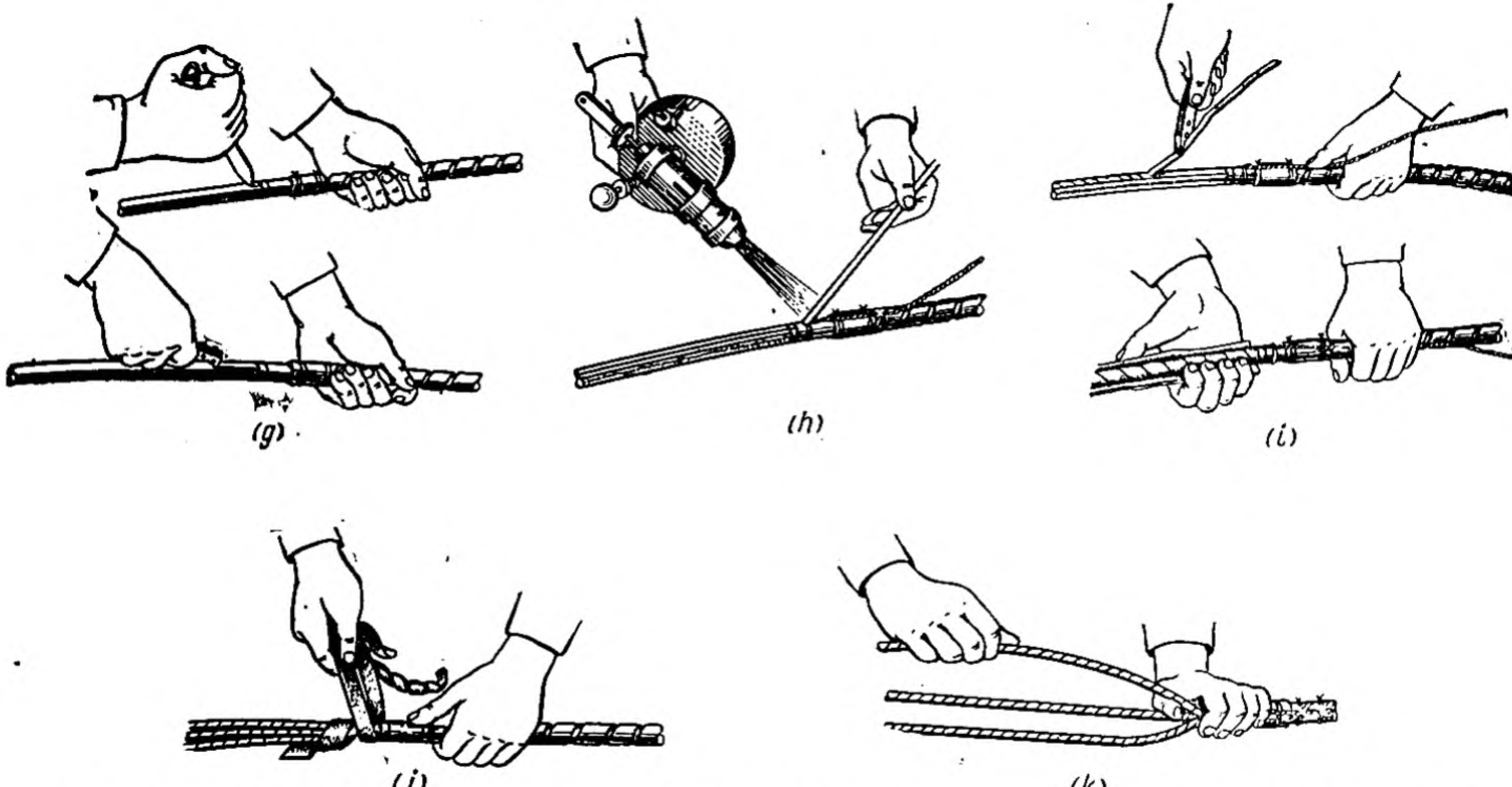

Fig. 196. Stepped dressing of a cable and attachment of the earthing conductor to its sheath and armour:
a—applying banding over armour, *b*—cutting armour through; *c*—pulling armour off, *d*—removing internal jute or cable yarn covering, *e*—removing protective paper tape layer, *f*—making circular notches in lead sheath, *g*—making longitudinal notching cuts, *h*—soldering earthing conductor to sheath and armour, *i*—removing lead sheathing, *j*—removing paper belt insulation, *k*—bend forming of conductors.

multi-strand copper earthing conductor not less than 16 sq mm in size is to be soldered with ПОС-30 (POS-30) tin-lead solder to the lead sheath and also to the armour directly in front of the banding on the armour (Fig. 196*h*). The flux used for this work should be a soldering paste of the type used to solder copper conductors.

Prior to securing the earthing conductor, both the lead sheath and the armour must be thoroughly cleaned. In addition, the armour is tinned.

After the earthing conductor has been soldered on, the lead strip formed between the two longitudinal cuts is ripped out with pliers up to the circular notch and the remaining part of the sheath end is spread open and removed from the cable (Fig. 196*i*).

The circular belt over distance T is to be removed later immediately before the cable end is made up, for example, into a spliced joint, or put into a sealing bell. This ensures that the insulation remains protected at the most vital spot, i.e., at the point where the conductors are bent to spread them apart. This point is termed the *crotch*.

After removing the lead sheath, the hands and all the tools must be thoroughly wiped clean with a rag wetted with petrol.

Next, the belt insulation is removed. Tear it off at the end of the remaining band of exposed lead sheathing (Fig. 196*j*). A knife should not be used for this purpose as it can injure the conductor insulation. The filler yarn can now be cut off, directing the knife blade in a direction not perpendicular to, but along the conductors and toward the undressed part of the cable. The filler yarn can also be nipped off with sharp end-cutting pliers. The freed insulated conductors can now be spread to form the crotch, the bending being done either by hand (Fig. 196*k*) or with the aid of a special template. Conductors require smooth bending free from any sharp changes in curvature.

All further dressing operations on the cable depend upon the method by which the cable is to be jointed or terminated.

Whenever a cable taken from a newly started drum or coil is to be dressed for jointing or termination, its ends require checking for the presence of moisture. For this, a banding of wire is applied, as explained above, to the cable 200 to 250 mm from the end. The cap* is then removed, the various coverings and armour untwisted down to the lead sheath, the lead sheath opened and the two top-layer tapes and two bottom-layer tapes of the paper belt insulation torn off. These tape samples are then submerged in molten paraffin heated to

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* Cap is the term used for the lead cup-shaped sealing tip soldered over the end of the cable to keep it air-tight. A cap can also be of temporary nature. In the latter case the end of cable is sealed with a wrapping of tarred tape which is given a top coating of cable compound.

a temperature of about 150°C. The paper insulation taken from the separate phase conductors is also subjected to this same procedure. If any moisture is present in the paper, a characteristic crackling sound will be heard and foam will appear on the surface of the paraffin.

There also exists another method. It consists in setting a paper sample afire. If moisture is present in the paper, it will burn with a crackling sound and foam.

If a test shows that moisture is present in the cable, a piece one metre long should be cut off and the fresh end of the cable again checked for moisture.

6. *Cable Termination and Jointing.*

Power Cable Termination in Sheet-Metal Sealing End Bells

For sealing the ends of cables installed within dry-atmosphere, heated and unheated, premises use is made of sheet-metal, normal-size and small-size conical, oval- and round-shaped sealing end bells.

Normal-size end bells are used on cables for voltages up to 10 kv; small-size end bells, on cables for voltages up to 1 kv.

The operations of sealing a cable in an oval-shaped, sheet metal end bell begin with dressing of the end of the cable after the thoroughly cleaned end bell has been slipped over the cable and out of way so as not to interfere with the dressing work.

The cable is dressed by following the same sequence of operations stated above, up to removal of the belt insulation, in accordance with the data listed in Table 20 and the dimensions shown in Figs 197 and 198.

When the dressing is completed, the earthing conductor is attached and soldered to the cable.

The next operations consist in removing the belt insulation, trimming the filler yarn and applying two layers of rubberised or p. v. c. tape over the insulation of each cable conductor. The tape wrapping is begun 25 to 30 mm below the level which the upper edge of the end bell is to occupy later. Following this, the cable conductors are

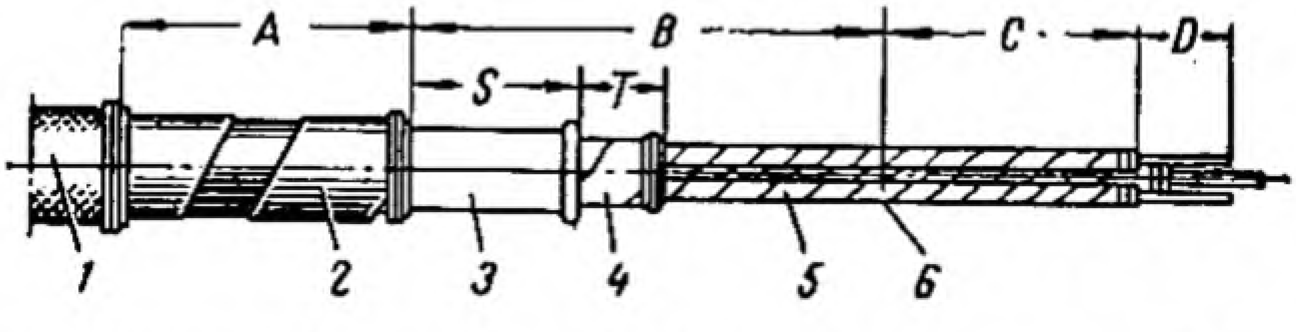


Fig. 197. Cable step-dressed for sealing in an end bell:
1—banding applied over cable armour, 2—steel-tape cable armour, 3—lead or aluminium sheath of cable, 4—paper belt insulation, 5—cable conductor in its paper insulation, 6—line corresponding to upper edge position of end bell.

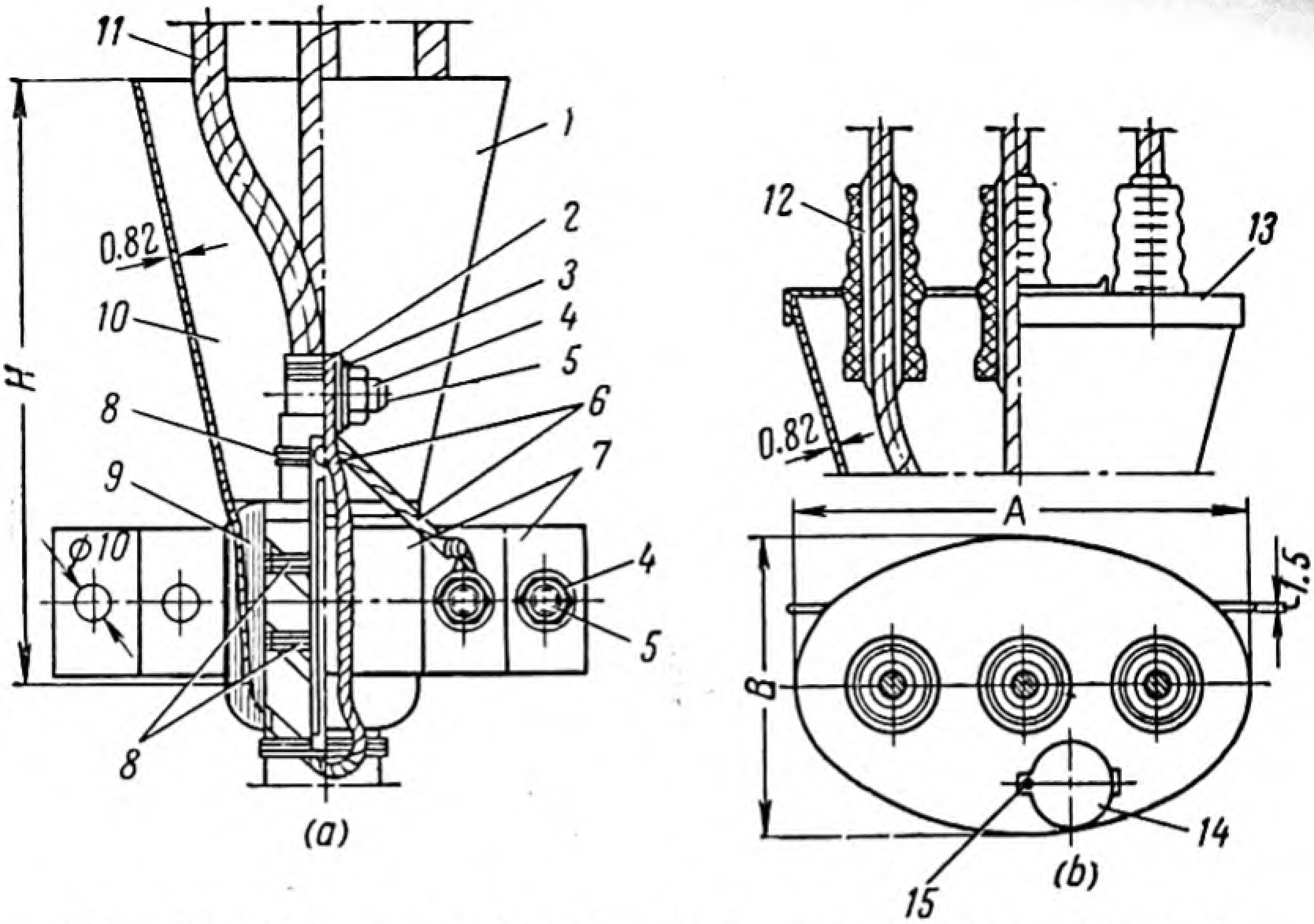


Fig. 198. Cable end sealing in sheet-metal oval-shaped end bell:
a—general view with half section, b—upper part of end bell having a cover; 1—end bell, 2—sheet-metal ear, 3—steel washer, 4—M8 steel nut, 5—M8 steel bolt, 6—copper earthing conductor, 7—steel half-clamps, 8—bandings of wire, 9—tarred tape, 10—thread banding, 11—cable conductor served with insulating tape, 12—porcelain bushing, 13—sheet-metal end-bell cover, 14—filling hole cover, 15—steel-rivet pivot.

Table 20

Data for Power Cable Termination with Full-Size Sheet-Metal, Oval-Shaped Sealing End Bells

Type of end bell	Cable conductor size (sq mm); cable rated for:		End bell dimensions, mm (Fig. 198)			Cable dressing dimensions, mm (Fig. 197)	
	6 kv	10 kv	*A*	*B*	*H*	*A*	*B*
BO-1 (VO-1)	Up to 16	—	158	96	215	125	170
BO-2 (VO-2)	25-50	Up to 16	180	112	250	140	200
BO-3 (VO-3)	70-120	25-50	212	130	300	160	240
BO-4 (VO-4)	150-185	70-120	244	148	340	180	265
BO-5 (VO-5)	240	150-185	264	162	370	190	290
BO-6 (VO-6)	—	240	282	172	395	200	305

Note. 1. Dimension *C* is selected on site to suit the job to be done.

2. Dimension *S* equals: 30 mm for all cables sealed with round- or oval-shaped full-size end bells; 20 mm for cables sealed in small-size end bells МГВ-1 and МГВ-2 (MGV-1 and MGV-2); and 25 mm for cables sealed in end bells МГВ-3 (MGV-3) and МГВ-4 (MGV-4).

3. Dimension *T* equals: 20 mm for all cables sealed in round- and oval-shaped full-size end bells, and 15 mm for all cables sealed in small-size end bells.

4. Dimension *D* is taken equal to the length of the cable-connector neck plus 10 mm.

spread and offset bent so as to conform with the general shape of the end bell and set so that they are equally spaced with respect to each other and with respect to the sides of the end bell. Also to be observed at this time is that the conductors are arranged in the phase order they must have for connection to the phased buses or apparatus terminals to which they have been brought up.

The portion of lead sheath over distance *T* can now be removed to apply a wrapping of unbleached thread over the revealed belt insulation to protect it from being torn and becoming unravelled. The end of the lead sheath is then slightly belled out with a special belling stick (Fig. 199).

The end bell earlier slipped on the cable is now raised for marking off its correct position on the cable with chalk or a coloured pencil and then lowered again, this time to apply a packing wrapping of tarred

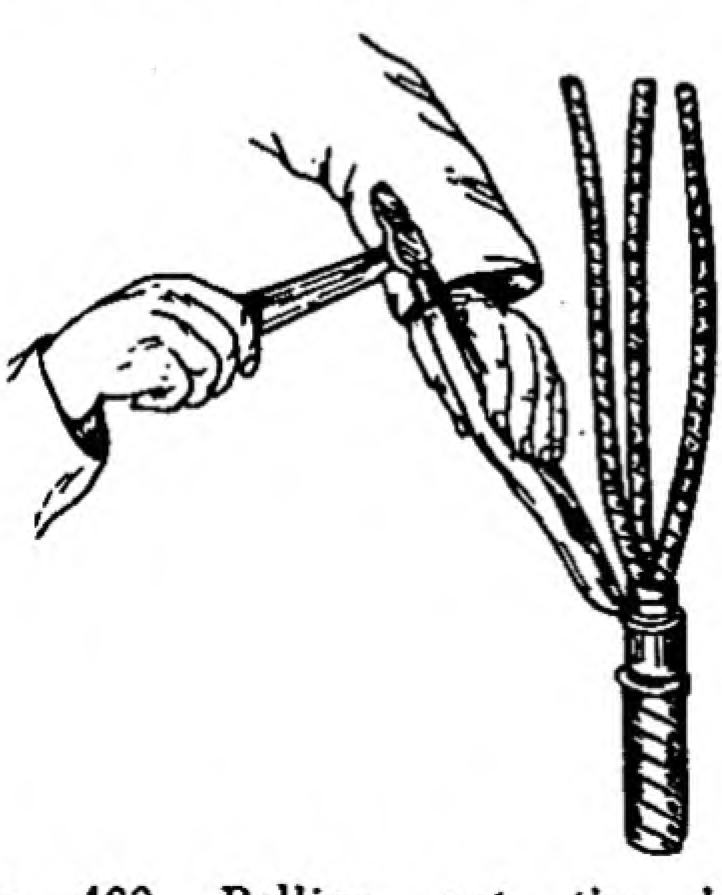


Fig. 199. Belling out the lead sheathing.

tape and tar paper over the cable armour at the place the end-bell throat must occupy. The earthing conductor should be run out from under this packing so that, after bell fitting, its end is free and outside of the end-bell throat.

The end bell is next raised and seated at its throat on the packing, following which the end-bell cover and the porcelain bushings are slipped over the conductors.

Fixing of the end bell and cable is accomplished with a strap clamp or bracket, the earthing conductor brought out from under the throat end being first bent upward and passed under the fixing clamp for connection to the earthing bolt on the end bell and to the clamp proper.

The cable conductors rising out of the end bell are next trained up to the terminals they must be connected to, measured off and fitted with their cable connectors which are to be jointed by the compression method. For this the paper insulation is removed from the conductor over the distance *D* (see Fig. 197).

After being jointed to the conductors, the cable connectors can be fixed on the corresponding bus or apparatus terminals.

To seal the cable end, the end bell is filled with cable compound (grade МБ-90 [MB-90], a bitumen compound having a melting point of 90°C). The compound is heated to a temperature of 180-190°C in a special pail fitted with a cover and provided with a pouring nose (Fig. 200).

Fig. 200. Pail for heating cable sealing compounds.

Heating is carried out on a charcoal-fired brazier or a special electric compound heater. During heating the compound should be stirred with a metal bar first heated and wiped clean to avoid introducing dirt and moisture into the compound. To see that the compound is properly heated, its temperature is checked with a thermometer.

Before filling, the end bell should be warmed with the flame of a soldering torch to about 70°C. Filling is to be done gradually by pouring the compound into the filling hole in 2 or 3 stages. As soon as the first stage is completed (when the end bell is filled to three-quarters of its height) the compound is allowed to cool down to semiliquid consistency. This is not difficult to check through the filling hole. When the consistency is great enough, the second portion of compound is poured in to fill the end bell. The final portion is added to make up for the shrinkage which occurs in the compound as it cools.

To complete the job after filling, the end bell and its fixing parts are given a finish coating of asphalt varnish. The conductors are also finish coated with enamel in the colour required for each separate phase.

Power Cable Termination in Moulded Epoxide Resin Sealing Ends

Today it is wide practice to terminate cables by moulding on plastic sealing ends with the use of an epoxide resin compound. This is due to the fact that such sealing ends have high electric and mechanical strength; their heat and moisture resistance is high, they are air- and moisture-tight and have small dimensions and a relatively low cost.

The main component from which the end seal is moulded is an epoxide resin compound made up directly on the spot in the form of a mixture of 100 per cent of grade Э-4021 (E-4021) epoxide paste and 8.5 per cent of hardener No. 1.

After the hardener has been added to make up the compound, the mixture can be used for moulding within a period of 3 hours at ambient air temperatures between +8° and +15°C, and within a period of 1.5 hours at temperatures between +20° and +25°C. Compound not used before such periods of time expire becomes overviscous and unsuitable for moulding.

Cables may be terminated with epoxide compound sealing ends

Table 21

Cable Termination Data for Sealing Ends of Moulded-on Epoxide Compound

Termination size designation	Cable conductor size (sq mm); cable rated for:			Termination dimensions, mm (Fig. 201*a*)			
	1 kv	6 kv	10 kv	*D*	*C*	*K*	*a*
ЗЭ-1 (ZE-1)	2.5-10	—	—	48	105	45	40
ЗЭ-2 (ZE-2)	16-35	10	—	58	110	50	40
ЗЭ-3 (ZE-3)	50; 70	16-35	—	67	130	70	40
ЗЭ-4 (ZE-4)	95	50	16-35	71	135	75	40
ЗЭ-5 (ZE-5)	120; 150	70; 95	50; 70	82	155	90	45
ЗЭ-6 (ZE-6)	185	120; 150	95; 120	88	165	95	45
ЗЭ-7 (ZE-7)	240	185	150	96	185	110	50
ЗЭ-8 (ZE-8)	—	240	185; 240	105	200	125	50

in heated and unheated, dry and damp premises the latter with a relative humidity up to 95 per cent.

The highest voltage for which the epoxide compound can be used is 10 kv.

Prior to commencing cable end sealing, the size and dimensions of the termination must be selected (from Table 21 and Fig. 201*a*) according to both the size and voltage rating of the cable. Following this, the cable can be prepared for end sealing by the usual stepped dressing method.

The dimension for each step in dressing the cable should be taken from Table 22 after reference to Fig. 201*b*. This preparatory work also includes the banding and soldering of the earthing conductor to the cable and then compression jointing of the cable lugs to the cable conductors.

The cylindrical parts of the cable connectors and of the lead or aluminium sheath as well as the bared portions of the cable conductors must next be thoroughly cleaned and then degreased by wiping them off with a cloth wetted with acetone or petrol.

The bared areas on the conductors and the end-face surfaces of the cable connectors at their cylindrical ends can now be coated with epoxide compound and the groove-like

Table 22

Main Dressing Dimensions for Cable Termination

Termination size designation	Dimensions, mm (according to Fig. 201*b*)			
	A (min)	*B* (min)	*S*	*T*
ЗЭ-1 (ZE-1)	560	400	80	20
ЗЭ-2 (ZE-2)	560	400	80	20
ЗЭ-3 (ZE-3)	560	400	80	20
ЗЭ-4 (ZE-4)	590	430	80	20
ЗЭ-5 (ZE-5)	625	460	85	20
ЗЭ-6 (ZE-6)	670	500	85	25
ЗЭ-7 (ZE-7)	675	500	90	25
ЗЭ-8 (ZE-8)	675	500	90	25

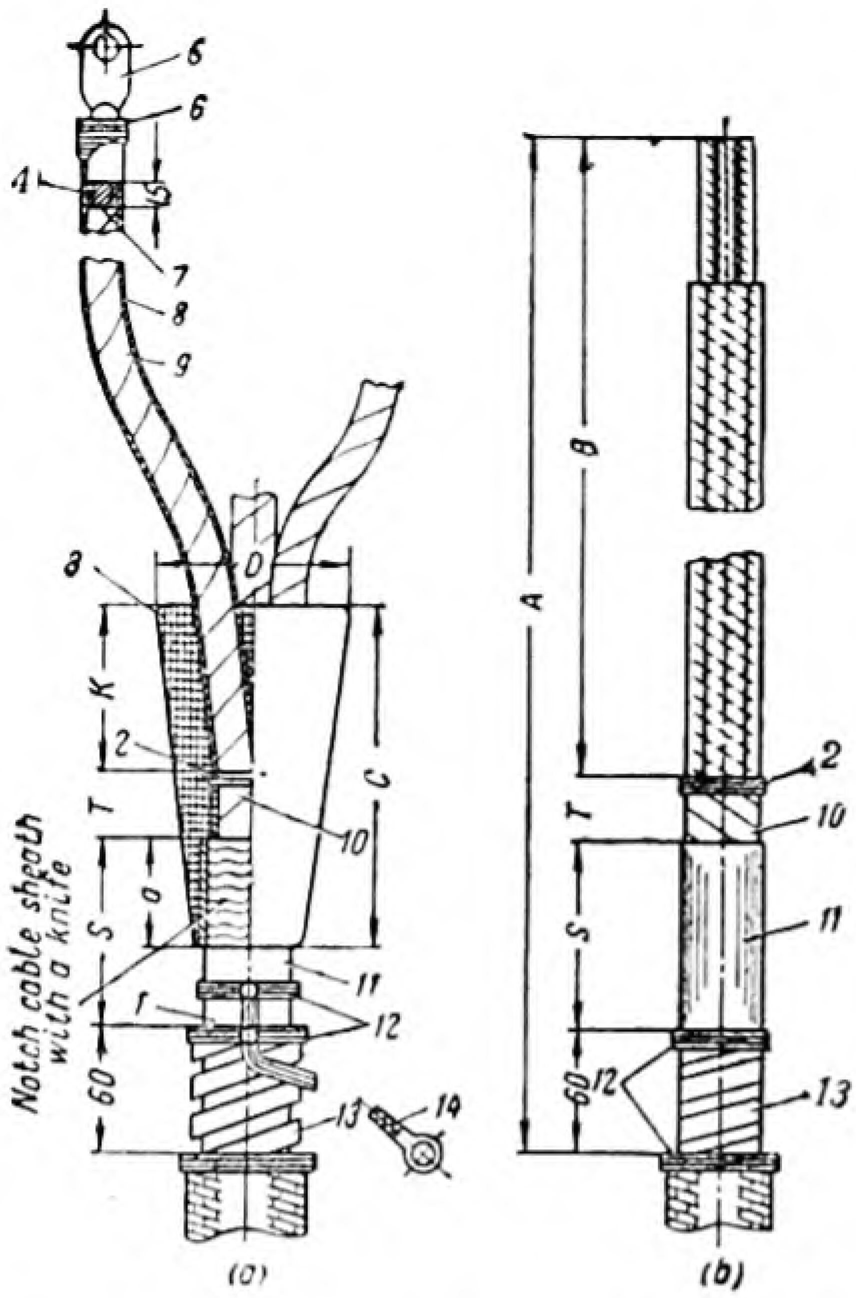


Fig. 201. Cable end sealing with use of epoxide compound:

a—general view with partial section of end seal, *b*—step dressing of cable for end sealing; *1*—earthing conductor soldered to sheath and armour, *2*—cotton yarn banding, *3*—moulded epoxide compound end bell, *4*—underserving of cotton tape over bared part of conductor, *5*—cable connector, *6*—string banding, *7*—cable conductor, *8*—cotton tape wrapping coated with compound, *9*—conductor (or phase) insulation, *10*—belt insulaton, *11*—lead sheath of cable, *12*—wire bandings, *13*—cable armour, *14*—terminated end of earthing conductor.

areas between the cable connector end and the cable conductor insulation filled level with a wrapping of cotton tape, each layer of which is given a coating of the epoxide compound.

After this the conductor insulation, the step of belt insulation and the bared lead or aluminium sheathing are also coated with the compound. Over the coating three layers of cotton tape, 15 to 20 mm wide, are then applied, each layer, in turn, also being thoroughly coated with compound. The first layer is wrapped from the cylindrical part of each cable connector towards the belt insulation. At the belt insulation the direction of wrapping is reversed. When the third layer is applied, it is wrapped on in the same direction as the first layer, but is run down to cover the belt insulation and the lead or aluminium sheathing.

To obtain air- and moisture-tightness and improve the appearance of the termination, it is recommended that the compound should have increased consistency when it is used to coat the cotton tape. This consistency is acquired by the compound 20 minutes after the epoxide paste and the hardener have been mixed at an ambient air temperature between +20° and +25°C, and one hour after the mixing has been done at an ambient temperature between +8° and +15°C.

It is necessary to coat the cotton tape with a continuous film of compound as the existence of uncoated areas reduces the dielectric strength of the termination and affects the air- and moisture-tightness of the cable.

A finish banding of twine is wound over the tape wrapping applied to the cylindrical portion of each cable connector. The surface of this banding is also coated with compound.

To make the termination at the crotch air- and moisture-tight, it is surrounded with

the moulding form after the internal surfaces are first coated with transformer oil. The compound from which the sealing bell is moulded is to be thoroughly mixed before pouring, and is to be poured after alignment of the form has been checked and all the cable conductors are set at the same distance from the edges of the form.

Filling is to be done with the compound at a temperature not under +10°C.

At ambient temperatures ranging from +8°C upward, the compound will harden and the form can be removed one day after pouring.

Voltage can be applied to the terminated cable three days after the form has been removed when the ambient temperature is greater than +15°C and six days after the form is removed when the ambient temperature is less than +15°C.

Forms should be slightly heated with a soldering torch flame prior to removal; when doing so remember that the compound is an inflammable substance.

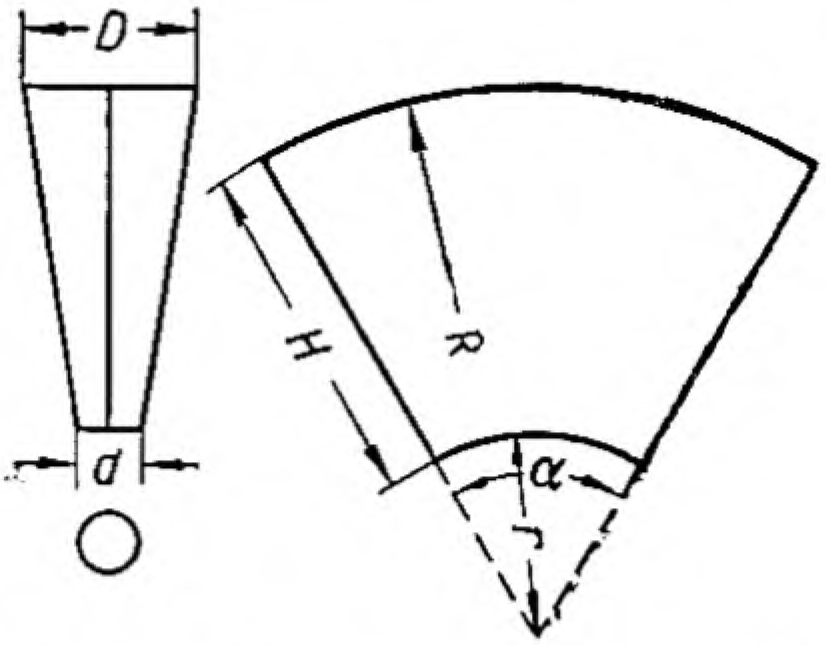


Fig. 202. Development of removable moulding form.

Forms are selected in accordance with the size of the termination. The dimensions for the developments of the forms can be seen in Table 23 and in Fig. 202.

One of the troubles run into during installation work is that some of the epoxide end seals lose their air-tightness. Most frequently this occurs at the point where the conical portion

Table 23

Dimensions of the Developments of Removable, Compound-Moulding Forms

Termination size designation	Development dimensions, mm (Fig. 202)					
	α	*R*	*r*	*H*	*D*	*d*
39-1 (ZE-1)	58	149	44	105	48	14.0
39-2 (ZE-2)	59	175	65	110	58	21.5
39-3 (ZE-3)	58	207	77	130	67	25.0
39-4 (ZE-4)	51	249	114	135	71	30.5
39-5 (ZE-5)	51	288	133	155	82	36.0
39-6 (ZE-6)	50	317	152	165	88	42.5
39-7 (ZE-7)	49	350	165	185	96	46.0
39-8 (ZE-8)	45	417	217	200	105	54.0

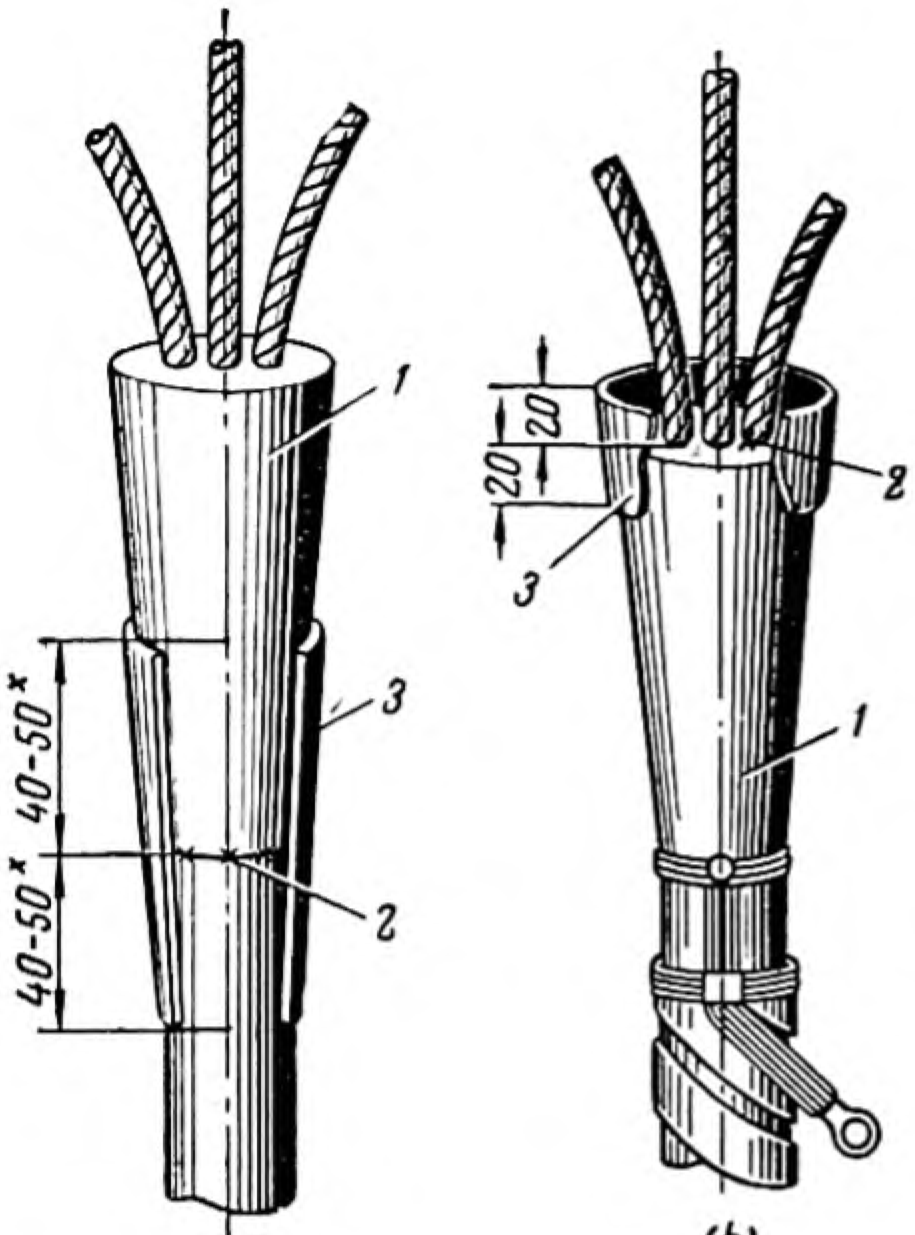


Fig. 203. Placing of temporary repairing form on end of cable being repaired:

a—form used to stop leaking of compound down cable sheath, *b*—form used to restore air- and moisture-tightness where phase conductors rise out of sealing end bell; *1*—moulded end bell, *2*—point of compound leakage or loss of air- and moisture-tightness, *3*—repair form.

of the end seal begins and where leakage of the compound is usually detected. To restore the air-tightness and stop leakage of the compound, the last 40 to 50 mm portion of the end seal and the same length of the lead or aluminium sheath below it must be degreased to begin repair. Following this, the lower portion of the end seal and 10 to 15 mm of the neighbouring portion of the lead or aluminium sheath are served with two layers of cotton tape coated with compound and a repair form is secured around the defective area (Fig. 203*a*). When the compound after pouring acquires full hardness, the form is removed.

The air-tightness can be lost where the conductors rise out of the end seal cone. To restore the air-tightness, the top flat surface of the end seal and the surfaces of the cable cores over a distance of 30 to 40 mm upward from the seal surface must first be degreased and then have a repair form placed around the end seal for additional filling with compound as shown in Fig. 203*b*.

"Dry" End Sealing of Cables with Polyvinyl Chloride Tape and Varnish

"Dry" end sealing of cables is practised in outdoor and indoor installations for voltages up to 10 kv. Such terminations require reliable protection from atmospheric precipitation (rain, snow) and from sunrays.

To dry-end-seal a cable, the end of the cable is step-dressed and the earthing conductor is banded on and soldered to the sheath and armour. The step dimensions to be observed during dressing are those given below (according to Fig. 204).

Dimension S, if the lead or aluminium cable sheath is not over 25 mm in diameter, is taken equal to 50 mm; if the cable sheath diameter is between 25 and 40 mm, equal to 80 mm; if between 41 and 55 mm, equal to 100 mm.

Dimension T, for 1-kv cables, is taken equal to 15 mm; for 6-kv cables, equal to 20 mm, and for 10-kv cables, equal to 30 mm.

Dimension B is selected on site, but must not be less than 400 mm on 10-kv cables, 250 mm on 6-kv cables, and 150 mm on 1-kv cables.

Dimension E depends upon the design of the cable connector and may range from 15 to 55 mm, depending upon the size of the cable conductor.

After a cable has been step-dressed as required above, the cable connectors are compression jointed on the ends of the conductors.

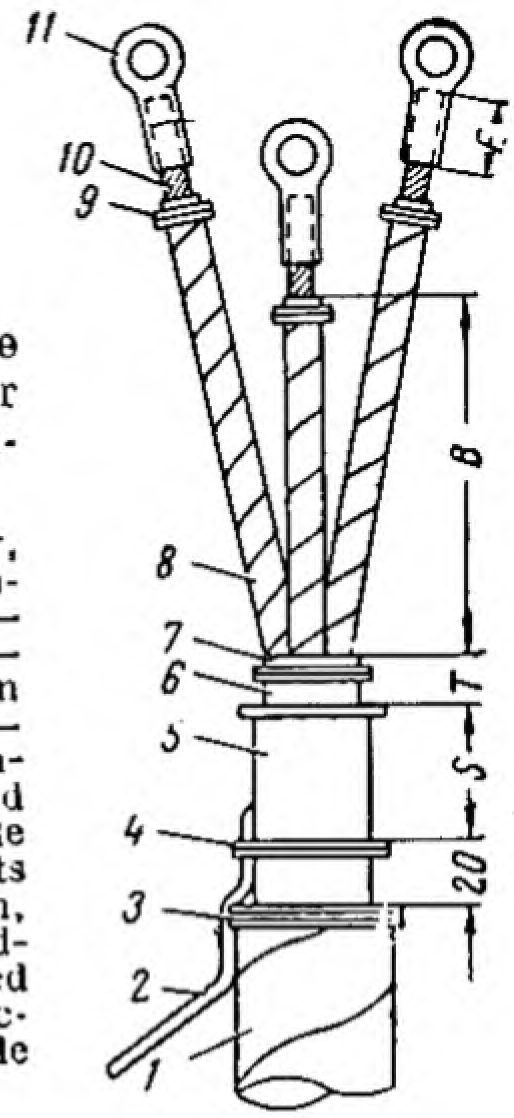


Fig. 204. Cable dressing for "dry" end sealing:

1—cable armour, *2*—earthing conductor, *3* and *4*—wire bandings, *5*—lead or aluminium cable sheath, *6*—paper belt insulation, *7*—thread banding, *8*—cable conductor in its factory insulation, *9*—thread banding, *10*—bared portion of conductor, *11*—cable connector.

To clean off any excess impregnating compound, the surfaces of the belt and conductor insulation, the bared lead or aluminium sheathing and the cylindrical portions of the cable connectors are wiped off with a cloth wetted in petrol. After this cleaning, each cable core, beginning from the belt insulation and up to three-quarters of the cylindrical portion of the cable connector, is half-lap wound with two layers of p. v. c. tape (when end sealing 6- and 10-kv cables, one layer of varnished-cloth tape is first wound over the conductor paper insulation). The following step consists in applying a coating of p. v. c. varnish paste to the p. v. c.-taped surfaces, beginning from the end of the belt insulation, over a distance of 70, 100 or 120 mm on cables having sheath diameters of up to 25, 40 and 55 mm, respectively. The conductors can now be brought closely together and secured by applying a banding *15*, of cotton tape and twine, as shown in Fig. 205.

The outer surface of the bunched-conductor section is again coated with p. v. c. varnish paste. Following this, a belt wrapping *9*, of p. v. c. tape, is applied to the lead or aluminium sheath section first degreased with petrol or acetone, and also to the bunched 70-, 100- or 120-mm section (bunched as stated above). To do the wrapping, a cross-over layer *16*, of the same kind of tape, is first wound over the belt insulation.

To secure finally the lower end of belt wrapping *9* and the ends of the wrappings at

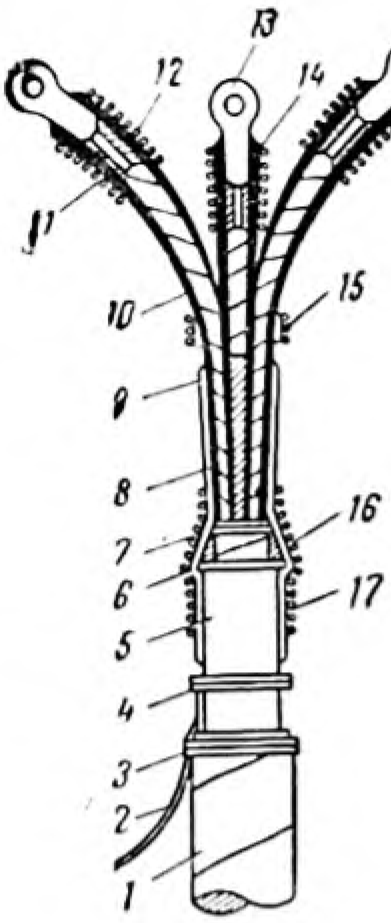


Fig. 205. General section view of a "dry" end sealed cable:

1—cable armour, *2*—earthing conductor, *3* and *4*—wire bandings, *5*—lead or aluminium cable sheath, *6*—paper belt insulation, *7*—thread banding, *8*—cable conductor in its factory insulation, *9*—belt wrapping of p. v. c. tape, *10*—p. v. c. tape wrapping over conductor, *11*—bared portion of conductor, *12*—conical smoothing wrapping of p. v. c. tape, *13*—cable connector, *14*—twine banding, *15*—banding of cotton tape and string, *16*—conical smoothing wrapping of p. v. c. tape, *17*—twine banding.

the cable connectors, bandings of twine, *14* and *17*, are added.

For improving the moisture resistance of the end seal and to provide it with a shiny surface convenient for removal of dust during service, the surfaces of the end seal are given a finish coating of asphalt varnish.

Jointing of Cables in Cast Iron Jointing Boxes

Cast iron jointing boxes are used to splice cables rated for voltages up to 1 kv. First the cable ends are dressed in steps having the dimensions listed in Table 24 and shown in Fig. 206*b*.

When dressing has been completed, the earthing conductor soldered in place and the conductors spread and shaped, the cable ends can be jointed together. For this, the paper insulation is removed from the cable conductors over the distance *E*, the ends of the conductors are slipped into the corresponding jointing sleeves and the joints made by compression jointing with a type РГП-7 (RGP-7) hand-operated hydraulic press. Where the paper insulation ends on the conductor, it is to be

Table 24

Data for Cable Splices in Cast Iron Jointing Boxes

Type of jointing box	Main jointing box dimensions, mm (Fig. 206*a*)				Cable conductor size, sq mm		Cable dressing dimensions (Fig. 206*b*)			
	L	*H*	*O*	*F*	three-core cables	four-core cables	*A*	*B*	*C*	*D*
M-40	580	164	140	70	Up to 35	Up to 16	295	125	170	115
M-50	720	180	150	90	50-95	25-70	365	135	230	175
M-60	830	210	180	100	120-185	95-150	420	155	265	210
M-70	900	250	220	110	240	185	455	160	295	240

Note. 1. Good practice is to take dimensions *S* and *T* for all sizes of cables equal to 35 and 20 mm, respectively.

2. Dimension *E* is equal to half the length of the jointing sleeve plus 10 mm.

secured with a banding of unbleached thread.

Next, two porcelain conductor separating plates are put in between the conductors, on both sides of the jointing sleeves,* the undercut ring of lead sheathing left on the cable during step dressing is removed and the belt insulation bared at this point is secured with a banding of unbleached thread. The ends of the lead sheathing can then be slightly belled out with a wooden belling stick.

The next operation is to place the lower half of the cast iron jointing box, first cleaned and wiped off, under the jointed cable. Those parts of the cable which are to rest in the box throats must be given a wrapping of tar paper and tarred tape. After this, the joint assembly is lowered into the jointing box, the earthing conductor is connected to the earthing bolts, the packing grooves of the box stuffed with jute or sacking impregnated by boiling in a bitumen compound, and the top half of the jointing box put in place and bolt jointed to the lower half.

Before a jointing box can be filled with the cable compound the box must be heated with a soldering torch flame. Cable compound will not adhere to a cold box surface and if poured into a cold box will, on congealing, leave between itself and the box surfaces free spaces in which moisture will be able to condense.

Cast iron jointing boxes to be buried in earth trenches require filling with grade МБ-70 (MB-70) bitumen compound; in heated premises the boxes should

* If the cable conductors are jointed by a soldering method, the porcelain spacing plates must be slipped over the ends of the cable conductors prior to jointing them to each other.

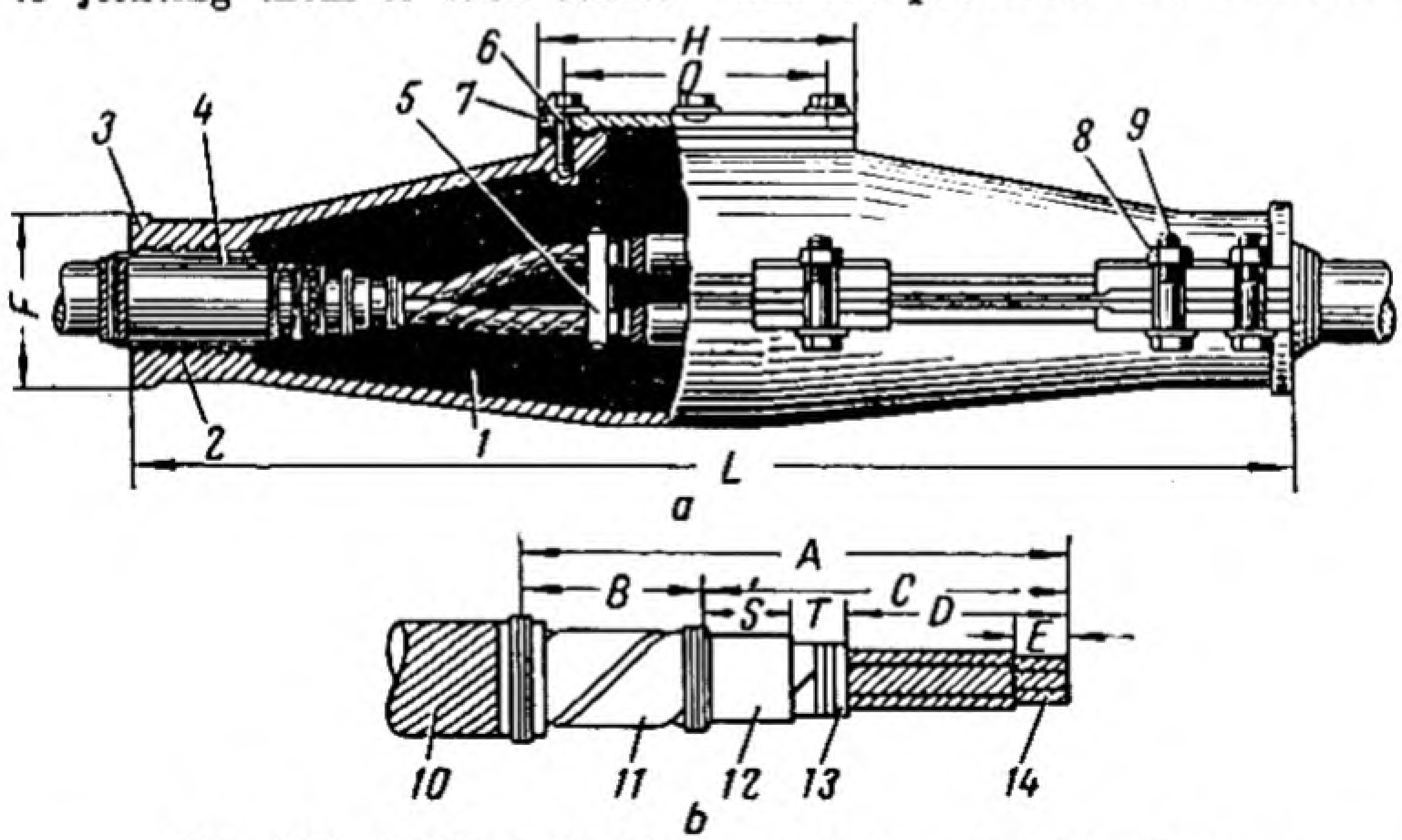


Fig. 206. Cable spliced in a cast iron jointing box:

a—general view with partial section, b—stepped dressing of cable end; 1—bitumen cable compound filling, 2—lower half of jointing box, 3—upper half of jointing box, 4—packing at box throats, 5—porcelain separating plate, 6—cover bolt, 7—box cover, 8—nut of box jointing bolt, 9—box jointing bolt, 10—jute covering, 11—cable armour, 12—lead or aluminium sheath, 13—paper belt insulation, 14—conductor.

be filled with grade МБ-90 (MB-90) bitumen compound.

Jointing boxes installed out-of-doors or in unheated premises where the temperature can drop to a minimum of —35°C must be filled with grade МБМ-1 (MBM-1) frost-resistant cable compound. Where the temperature can drop to —45°C, filling must be done with grade МБМ-2 (MBM-2) frost-resistant compound.

The compound should be poured in several steps; at first the box space is filled to one half its free volume, next, after the first portion congeals to a semifluid condition, to three-quarters of full volume and, finally, enough compound is added to fill completely the cable box. During the intervals between pouring care must be taken to keep the filling hole covered with a clean rag. The bolts which join both box halves together are also tightened during the process of filling.

When the compound begins to solidify, in order to make up for any shrinkage, compound is added to fill the cable box up to the edge of the filling hole, after which the cover is bolted on to seal the box.

The fully assembled jointing box is to be given two coats of asphalt varnish, applied with special care at the joint seams and the bolt connections. It is good practice to pour additional hot cable compound over the bolt connections and the places where the cable enters the box throats.

A metal identification tag with a corrosion-resistant coating should be attached at the throat of a cable jointing box. This tag should indicate: the grade and size of the cable, the date of box installation and the full name of the cable jointer.

Jointing of Cables in Lead Sleeves

Lead sleeves are used in jointing cables for voltages of 6-10 kv.

Such a cable splice, in general, takes the form of a lead tube slipped over one of the cable ends far enough to allow the cable ends to be step-dressed and the conductors to be jointed and insulated, following which the tube is slipped back over the spliced section and lead-burned to the cable sheath for sealing at both ends, the last operations consisting in filling with compound and final sealing.

At the place where a sleeve joint is to be made the cable is protected with dry clean sacking to prevent any dirt from getting into the sleeve.

To make this type of joint, the cable ends are dressed according to the dimensions shown in Fig. 207 and the data listed in Table 25.

In these joints the earthing conductors are not soldered on after the cable ends have been dressed. This work is performed after the conductors have been jointed and the lead sleeve has been lead-burned to the lead sheath of the cable at both ends.

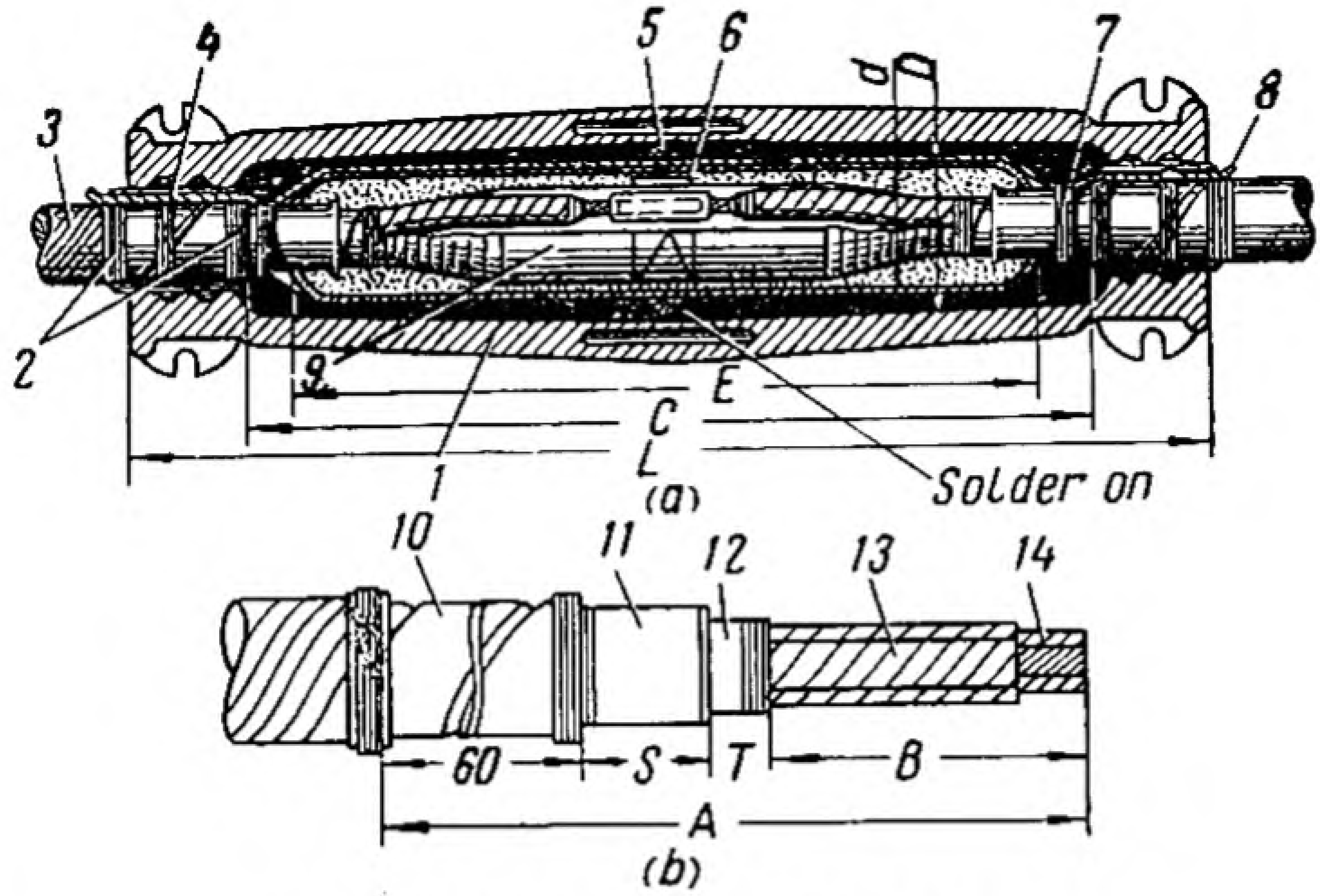


Fig. 207. Cable jointed in lead sleeve:

a—general sectional view of jointed cable, *b*—stepped dressing of cable end; *1*—protective cable box, *2*—bandings, *3*—jute covering, *4*—earthing conductor, *5*—wiring banding serving for earthing, *6*—banding of paper insulation, *7*—banding consisting of 3-4 turns of soft galvanised wire, *8*—throat packing, *9*—wide-tape paper wrap, *10*—cable armour, *11*—lead sheath, *12*—belt insulation, *13*—conductor insulation, *14*—conductor.

Table 25

Data for Jointing Cables in Lead Sleeves

Type of lead-sleeve joint	Type of box	Main dimensions of sleeve and box, mm (Fig. 207*a*)					Cable conductor size (sq mm); cable rated for:		Cable dressing dimensions, mm (Fig. 207*b*)	
		L	*C*	*E*	*D*	*d*	6 kv	10 kv	*A*	*B*
MC-60 (MS-60)	K-55	825	665	450	108	60	10-16	—	330	175
MC-70 (MS-70)	K-55	825	665	475	108	70	25; 35; 50	16-25	345	190
MC-80 (MS-80)	K-65	900	752	525	130	80	70; 95	35-50	370	215
MC-90 (MS-90)	K-65	900	752	550	130	90	120-150	70-95	380	225
MC-100 (MS-100)	K-75	1,020	860	600	149	100	185-240	120-150	405	250

Note: Dimensions S and T, for all sizes of cables, and as required by good practice, should be taken equal to 70 and 25 mm, respectively.

To joint the conductors, the conductor insulation is trimmed off over a distance equal to half the conductor-jointing sleeve length plus 10 mm, and is tied with unbleached thread at the trimmed end. Following this, the corresponding conductor ends are inserted into the jointing sleeves and the ends are forced to the centre. The bare surfaces of the conductors between the

ends of the jointing sleeves and the ends of the conductor insulation are next wrapped round with asbestos yarn or sheeting held in place with a serving of insulating tape. This is done to prevent the solder from leaking out of the jointing sleeve during soldering.

The soldering is done with grade ПОС-30 (POS-30) tin-lead solder, and either rosin or soldering paste is used as the flux.

The solder is heated in a melting pot placed in the flame of a soldering torch or on a special heating brazier. For pouring, a steel solder ladle is used.

The conductor joints are soldered beginning with the uppermost conductor, after which the middle joint and then the lowermost conductor joint are soldered. As each joint is soldered, the excess solder is wiped off with a rag before it can solidify. After the soldered jointing sleeves cool down completely, any remaining roughness on their surfaces is smoothed down with a fine-cut file and the temporary wrapping of asbestos yarn or sheeting is removed.

The conductor joints are next "scalded" by pouring hot, grade МП-1 (MP-1) scalding compound over the jointed areas. This compound serves to re-impregnate the insulation which has been dried by the heat of the soldering process. During this operation any moisture which has been taken up from the hands of the jointer by the paper insulation is driven out. Scalding is carried out with a metal pan placed under the cable, the hot compound being scooped for pouring with a steel ladle.

Next to be performed after scalding is to insulate the jointed sections with impregnated cable paper unrolled from rolls of narrow-tape or wide-tape paper. A set of such rolls of impregnated cable paper is taken to the cable jointing site in a closed metal container filled with the МП-1 (MP-1) scalding-impregnating compound. These containers also carry a definite amount of cotton yarn.

As a rule, the containers are first heated by submerging them in hot cable impregnating compound and then opened to take out the cable paper rolls as required. To avoid introducing any dirt or moisture, the rolls of paper and the yarn should be fished out with the aid of a metal hook.

The difference in insulating a joint area with narrow-tape or wide-tape paper consists in that wide-tape paper is easier to apply but narrow-tape paper better insulates the joint.

Narrow-tape paper insulation is begun by applying the wrapping over the bare sections of the conductors (between the conductor insulation and jointing sleeve). To level off these places a serving of cotton yarn is used.

The total thickness of the paper insulation at the joint area should equal about two times that of the factory insula-

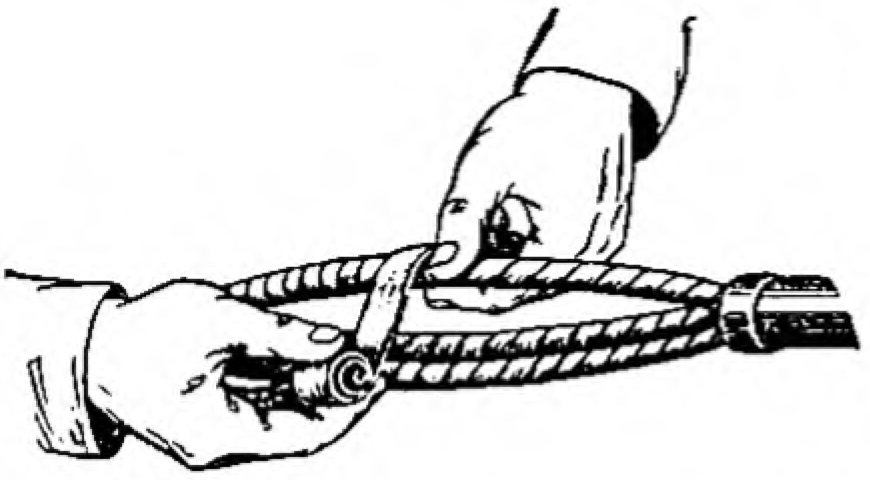


Fig. 208. Applying narrow-tape paper insulation.

tion, vernier calipers being used to do the checking.

The application of the narrow-tape cable paper insulation is illustrated in Fig. 208; wide-tape insulation, in its finished form, can be seen in Fig. 207*a* where it is marked as item *9*.

After the insulation has been wrapped over all three conductors, the conductors are brought together and secured with a common banding of cable paper unwrapped from a roll of 50-mm wide paper tape. This banding should be from 3 to 4 mm thick and be tied on with yarn so that the knot in the yarn falls between any two conductors and does not cause interference when the lead sleeve is subsequently slipped over the spliced section.

The undercut band of lead sheathing left on the cable when dressing can now be removed, the ends of the cable sheath slightly belled out, and the bared step of belt insulation tied down with thin unbleached thread or yarn. Following this, all the exposed paper-insulation surfaces are to be "scalded" with grade МП-1 (MP-1) scalding compound and the fitting of the lead jointing sleeve commenced.

This work is started by sliding the lead sleeve from the side it was slipped over when jointing was begun to a position over the jointed section. With the sleeve supported underneath by the left hand, its ends are now beaten down with a striking stick to give them a hemispherical shape.

As soon as both ends make a close fit with the cable sheath, the sleeve can be soldered to the lead cable sheath. Grade ПОС-30 (POS-30) tin-lead solder is used for this work. Stearine, МП-1 (MP-1) compound or a special paste prepared with beef tallow is to be employed as the flux. Before soldering, the places where the sleeve and lead cable sheaths are to be jointed must be well cleaned. In performing the soldering the soldering torch is held in one hand, the bar of solder in the other hand, and the torch flame directed alternately on the bar and the joint. As the solder melts, it is laid on the joint (Fig. 209).

The solder is distributed round the joint with a soft wiping cloth (Fig. 210) impregnated with flux. To check the under parts of the soldered joints, a mirror is held under the joint to inspect it.

Soldering must be performed with due care, otherwise the lead sheath or lead sleeve can be burned through. It is necessary to see that the flame is not held too long on any one spot and that the red-hot burner

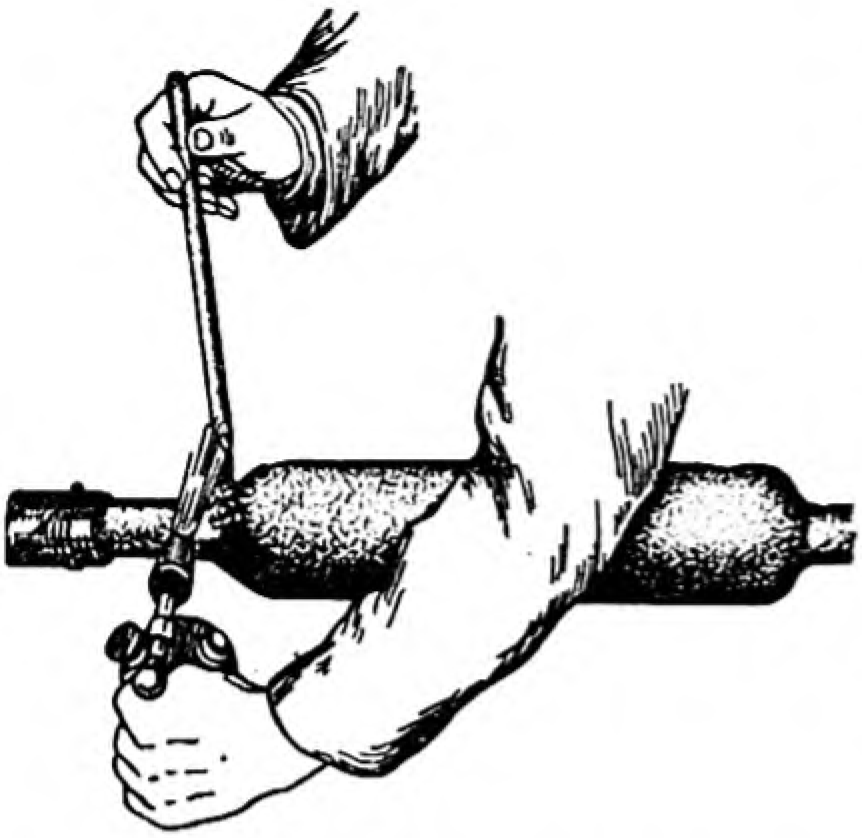


Fig. 209. Soldering the lead sleeve to the cable sheath.

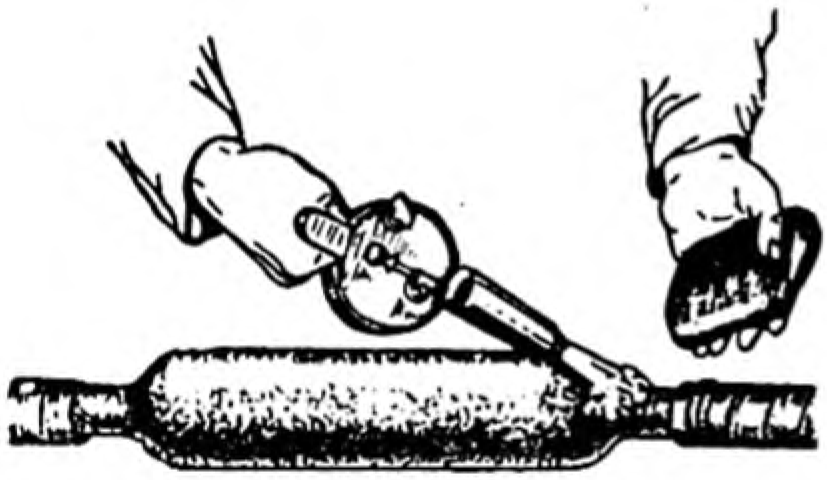


Fig. 210. Distributing the solder round the joint.

of the torch is never allowed to come in contact with the sleeve or lead cable sheath.

After one end of the sleeve has been soldered to the cable sheath, two V-shaped holes are cut on the top of the sleeve at both ends (see Fig. 211), and the other end of the sleeve is soldered to the cable sheath.

With both ends soldered on, the sleeve assembly must be laid at an angle of 8-10 degrees to the horizontal and filled with compound. Grade MK-45 mineral-oil-rosin compound having a melting point of 45°C, a flash point of 180°C and a pouring temperature of 130° to 140°C is used for this purpose.

The sleeve should be inclined so that the first portion of compound will drain out. This portion serves to act as a third "scald". When the compound begins to escape without bubbles, a sign that all the air and moisture have been driven out of the sleeve space, the sleeve should be set horizontally in order to stop further escape of the filling compound.

After the compound fully fills the sleeve, it is allowed to cool down and more compound is added to make up for the shrinkage of the compound. Following this, the two holes in the sleeve are closed and sealed with solder, and the earthing conductor attached. The latter operation is carried out by first attaching a flexible copper conductor not under 16 sq mm in size with bandings of soft binding wire and then soldering it to the cable armour and lead sheath at both sides of the lead sleeve and also in the middle of the sleeve.

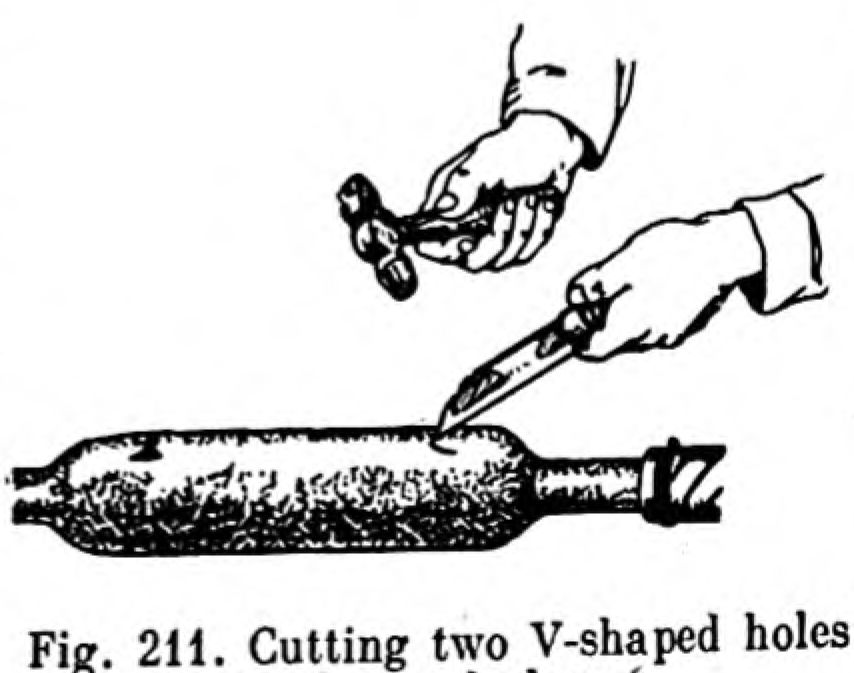


Fig. 211. Cutting two V-shaped holes in the lead sleeve.

To protect the lead sleeve surface from corrosion a coating of asphalt varnish is applied, and to protect the joint from mechanical injury the sleeve assembly is enclosed in a cast iron cable box. As in the case of cast iron box jointing a metal identification tag is attached to the cable at one of the box throats.

Specific Features of Aluminium Cable Conductor Solder Jointing

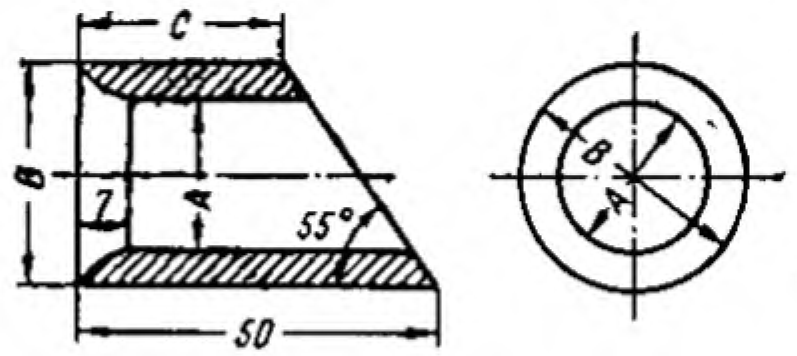
To solder aluminium cable conductors, the trimmed end of conductor insulation is first temporarily banded with soft binding wire, later replaced with a banding of unbleached thread or yarn. For cutting the end of each conductor to an angle of 55 degrees a trimming sleeve is slipped, in turn, over each conductor end to guide the hacksaw (the cutting being done along the sleeve slant face). The dimensions of trimming sleeves for various sizes of cable conductors can be seen in Table 26.

After trimming, the cut ends of the conductors are thoroughly washed with petrol and the face of each cut filed smooth to form one general surface. Remember that any strand left below the general surface will remain uncleaned and will not bond with the solder.

Each pair of conductor ends, now made ready by the above operations, is brought up against each other and enclosed in a steel split soldering form clamped about the conductor ends by bandings of wire pulled tight in the grooves provided at the ends of the form. To prevent the solder from escaping from the form, each end is sealed with a refractory mastic (chalk, clay, asbestos).

Table 26

Dimensions of Trimming Sleeves for Preparing Ends of Aluminium Cable Conductors for Solder Jointing



Conductor size, sq mm	Dimensions, mm		
	A	B	C
50	9.5	20	36
70	11.5	20	36
95	13	20	36
120	16	25	32.5
150	18	25	32.5
185	20	30	29
240	22	30	29

The solder is most conveniently melted in electrically heated crucibles or pots. However, it is very frequent practice to melt the solder in graphite or fireclay crucibles not suitable for electric heating. Solder heating in such cases is done on a portable fuel-fired heater (Fig. 212).

For performing the soldering, the crucible containing the molten solder is placed at one side of the joint to be soldered. Be-

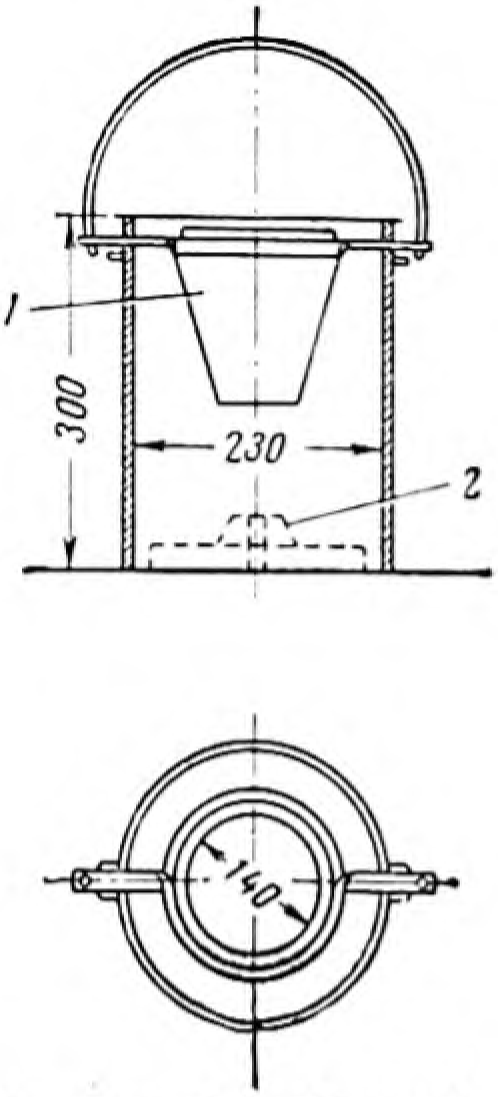


Fig. 212. Crucible and portable heater for melting zinc-base solder:
1—crucible, 2—burner nozzle.

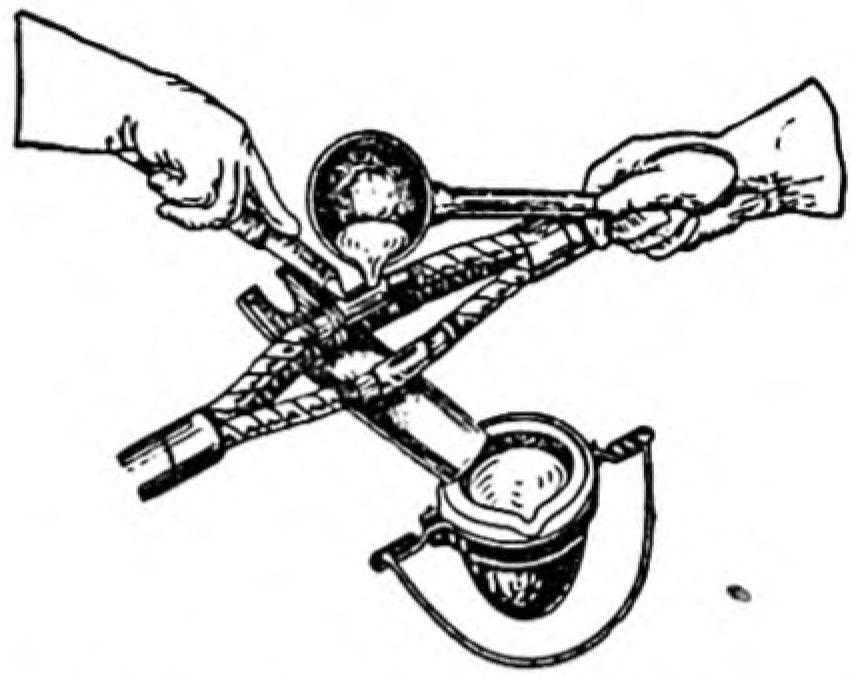


Fig. 213. Soldering aluminium cable conductors.

tween the crucible and the point where the joint is to be made a drip trough of sheet metal is next provided to drain the excess solder back into the crucible (Fig. 213).

The soldering is performed by the cable jointer and his helper. The job assigned to the helper is to pour first three or four ladles of solder over and into the form opening to heat the jointing surfaces. Then he must continue to pour ladles of solder into and over the solder-form opening. The cable jointer now begins to clean thoroughly the cable conductor surfaces submerged under the pool of solder, with a scraper made from two or three hacksaw blades. All three pairs of conductors in the cable are thus soldered together, one after another. Not over one and one half to two minutes should be spent in soldering each conductor. The paper insulation of the cable may become overheated and carbonised if a greater period of time is spent. Before soldering each following pair of conductor ends, care must be taken first to reheat the solder.

As soon as the soldering proper is completed and the jointed areas cool down, the forms are removed. A ready joint has the appearance represented in Fig. 214.

Soldering is done with grade ЦА-15 (TsA-15) solder consisting of 85 per cent zinc and 15 per cent aluminium by weight. This solder has a melting

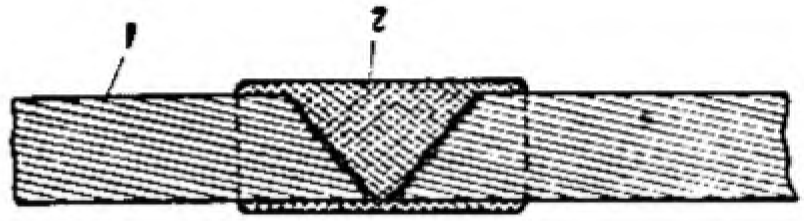


Fig. 214. Appearance (section) of soldered joint in an aluminium conductor:
1—cable conductor, 2—solder.

point of 435°C and should be heated to 550°-600°C. The crucible should contain at least 5 kg of solder. A smaller quantity of solder will cool down too quickly and be unfit for the work.

If copper-and aluminium cables must have their conductors jointed, they are soldered to each other by the same method used above, the only difference being that the soldering is done with grade ЦО-12 (TsO-12) solder consisting of 88 per cent zinc and 12 per cent tin by weight.

7. *Safety Rules for Cable Laying*

No member of a cable laying team or any other person should be allowed to stand in the path of a drum of cable when it is being rolled, particularly during lowering down an inclined platform from an automobile truck.

All projecting nails must be removed from unpacked drums of cable for they may become the cause of a serious injury during unreeling of the cable.

The men who handle drums of cable during lifting and rolling operations must wear canvas mittens. This rule also applies to the men who unreel the cable and do the laying.

When, during cable laying, the cable makes a turn in direction, no cable layer should be allowed to stand between the cable and the inner side of the trench about which the turn with the cable is made.

Work with cable sealing compounds and solder can be carried out only when canvas gloves designed to protect the hands and forearms up to the elbow are worn. Cable compounds must always be heated in a special pail fitted with a cover and designed with a pouring nose, the heating to be done on a brazier or electric heater. When the compound is mixed, the eyes should be protected with goggles and the mixing should be done with a metal rod, first well heated to avoid any spattering of the compound.

Never allow a pail containing hot compound to be passed from hand to hand. The man holding the pail must always place it on the ground to let the next man take it up with the handle free.

Remember that epoxide compounds are toxic and that medical rubber gloves must be worn when working with them. The room in which such compounds are handled should be well ventilated.

Chapter VI

FEATURES OF OVERHEAD POWER LINE ERECTION FOR VOLTAGES UP TO 1,000 VOLTS

1. General

Overhead electric power line (abbreviated as OL) is the name given to a circuit designed to transmit and distribute electric power over wires strung out-of-doors and fixed with line fittings and insulators to line supports arranged at intervals greater than 25 metres.

Line route is the term used to designate both the direction in which the line is run and the territory over which it passes.

The main elements of an overhead electric power line (OL) are: the line supports, insulators, wires and line fittings.

Depending upon their functions and the places they occupy in an overhead line, line supports are known as: terminal supports (at beginning and end of the line) which serve to take up the one-side pull of the tensioned line wires; angle supports, erected at the points where the line route makes a turn in direction to withstand the resultant force created by the pull of the wires on both sides of such supports, and intermediate supports which serve to support the wires over the straight sections of the line route.

The height of the line supports depends upon the height at which the line wires must be suspended. This height is the sum of the height called the clearance to earth and the sag of the wire span (Fig. 215).

Clearance to earth is the term used for the distance from the wire to earth at the point of greatest sag in the wire.

The clearance to earth of the wires of a line is prescribed according to the nature of the territory through which the line is passed and the voltage at which the line is operated.

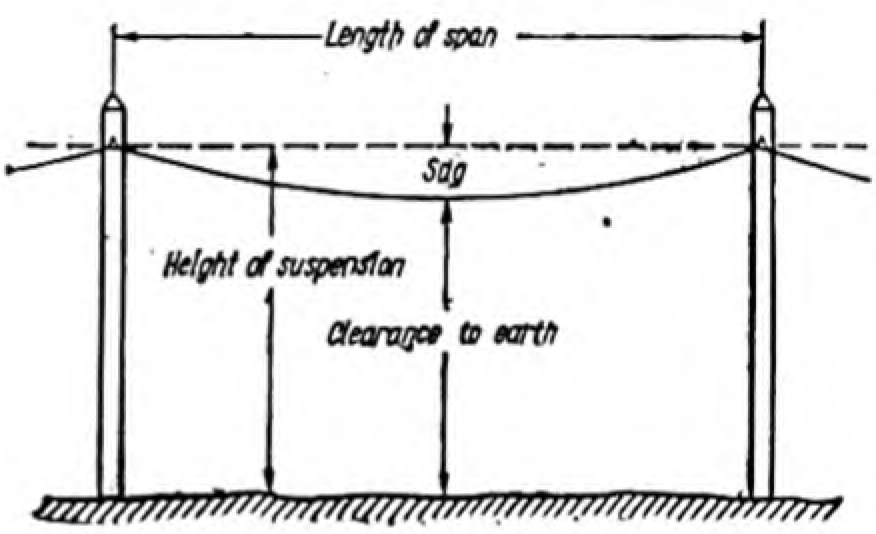


Fig. 215. Main dimensions governing overhead line erection.

For low-voltage lines (up to 1,000 v) the following clearances to earth must be observed:

1) in populated localities—not less than 6 metres;

2) in unpopulated localities—not less than 5 metres;

3) in places difficult of access for persons and inaccessible for transport facilities—not less than 4 metres.

At intersections with highways and railways, and also other kinds of service facilities, the clearance must be increased to 7-7.5 metres.

Sag in a wire is the distance from the wire at the middle of a span to an imaginary line

drawn between the points of support at both ends of the span. The sag in a wire depends upon the loading of the wire; the loading, in turn, is dependent upon the length of the span (distance from pole to pole) and the material and size of the wire. Span lengths for overhead lines with voltages up to 1,000 volts usually range from 35 to 45 metres. When the total length of a line support is selected, it is necessary to make allowance for the depth to which the line support must be buried in the soil. For normal erection conditions the depth varies from 1.4 to 1.8 metres.

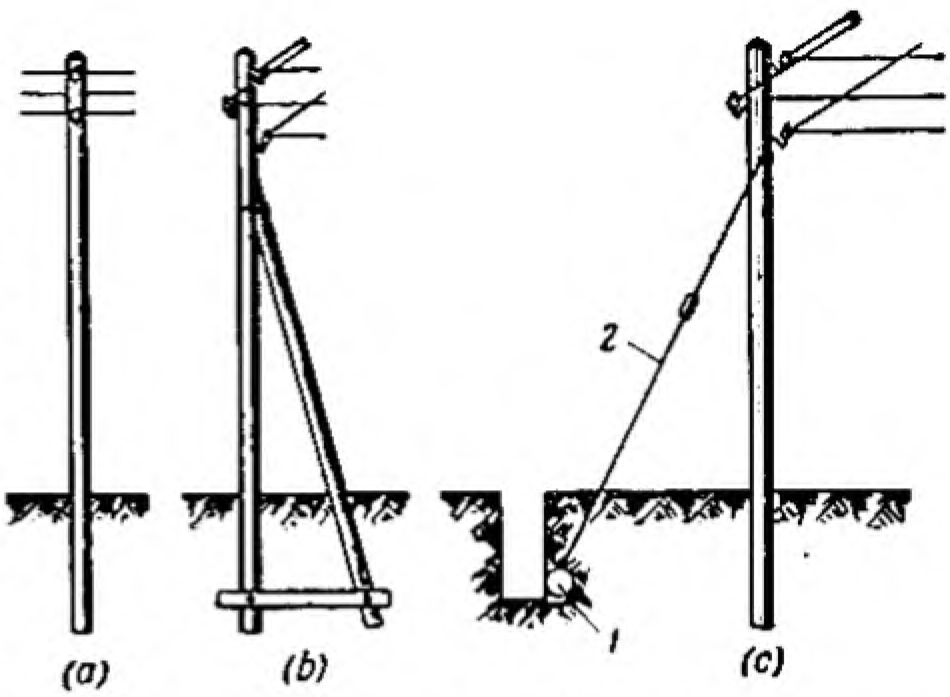


Fig. 216. Wood pole supports:
a—straight pole, *b*—straight pole with bracing pole, *c*—wire-guyed pole: *1*—guy anchor, *2*— guy wire (cable).

2. Line Supports and Their Erection

Overhead power lines for voltages up to 1,000 volts are generally erected with pine pole supports, the poles being not less than 15 cm in diameter at the top and free from signs of rot and worm holes.

For the intermediate line supports, single straight poles are used—see Fig. 216*a*. The terminal and angle line supports are made of combined construction in which the main pole is either jointed with a bracing pole placed on the side where the resultant pull of the line wires can be taken, or is supplied with a guy wire arranged on the side opposite the resultant pull exerted by the wires (Figs 216*b* and *c*).

Brace poles are fitted to their straight poles by cutting a joint notch in the straight pole to a depth not over one-third of the pole diameter and then joining them together with a through bolt. The point at which a bracing pole is jointed or the guy rope is attached to the straight pole is selected so that it is below the level at which the wires are strung.

To secure guy wires at ground level, some kind of an anchor is buried in the soil as shown in Fig. 216*c*. Guy wires may also be fixed to brick and concrete buildings and to other suitable kinds of structures.

When logs of the necessary length are unavailable, the poles are made of two-piece construction. The lower part of such a two-piece pole is called the stub or stub pole and is generally the shorter of the two parts (Fig. 217).

Where both parts are to be bound together, they are slightly hewed to form flat jointing surfaces. The hewing plane should

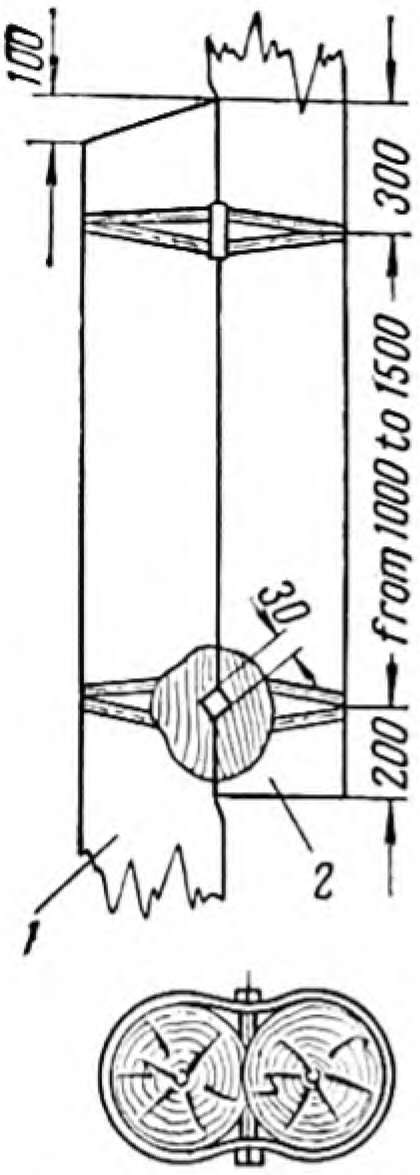


Fig. 217. Main support pole jointing to a stub pole:
1—stub pole, 2—main support pole.

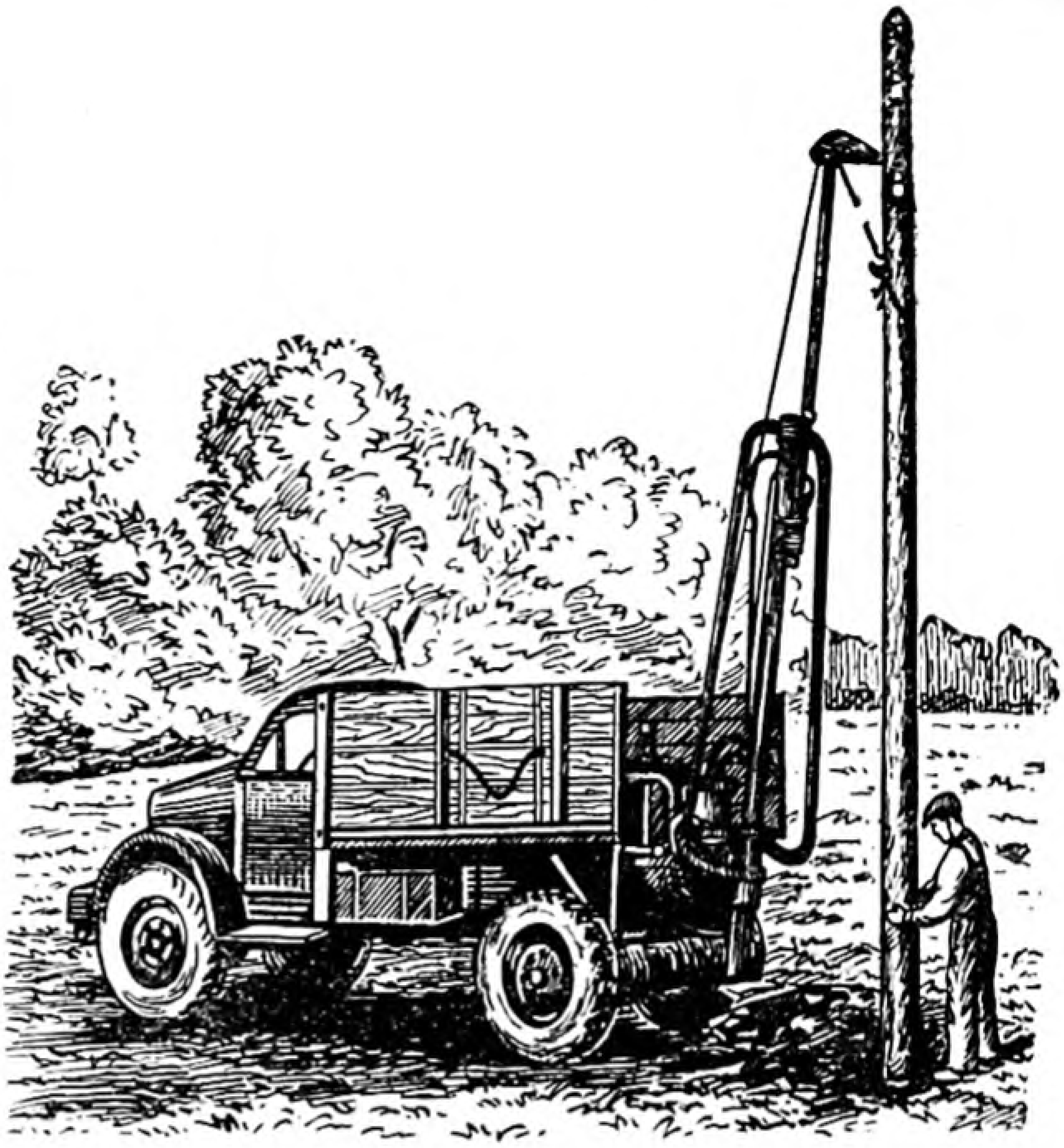


Fig. 218. Truck-mounted hole borer and pole setter.

be made to face the line direction and thus give the pole greater flexibility. Hewing is to be done over a distance of 1.5 to 1.8 metres and the pole parts joined together by two bandings of 4-mm diameter galvanised steel wire, each consisting of 8 to 12 turns of wire. The distance between the bandings is taken equal to 1-1.3 metres.

The pole ends to be set in the soil require some method of preservation treatment, i. e., must be impregnated or treated with an antiseptic solution to make the wood resistant to decay.

Poles of limited height and weight should be set with the aid of truck-mounted, hole-boring and pole-setting rigs (Fig. 218). High and heavy poles require setting with a winch and an A-frame pole rigged with guy lines for safety during lifting (Fig. 219).

Every pole, as soon as it stands in its hole, must be aligned:

1) by turning it about its axis to bring the insulators in the necessary position relative to the line route;

2) by means of a plumb line to have it truly vertical.

Another alignment needed when placing poles is to see that they all stand exactly in one line within any given straight section of the route.

As soon as a pole is fully aligned, it can be permanently

set by tamping in the earth earlier dug from the hole, the backfilling being done in layers of 150 to 200 mm thoroughly tamped in one after another.

In the U.S.S.R. it is now wide practice to use reinforced concrete line supports.

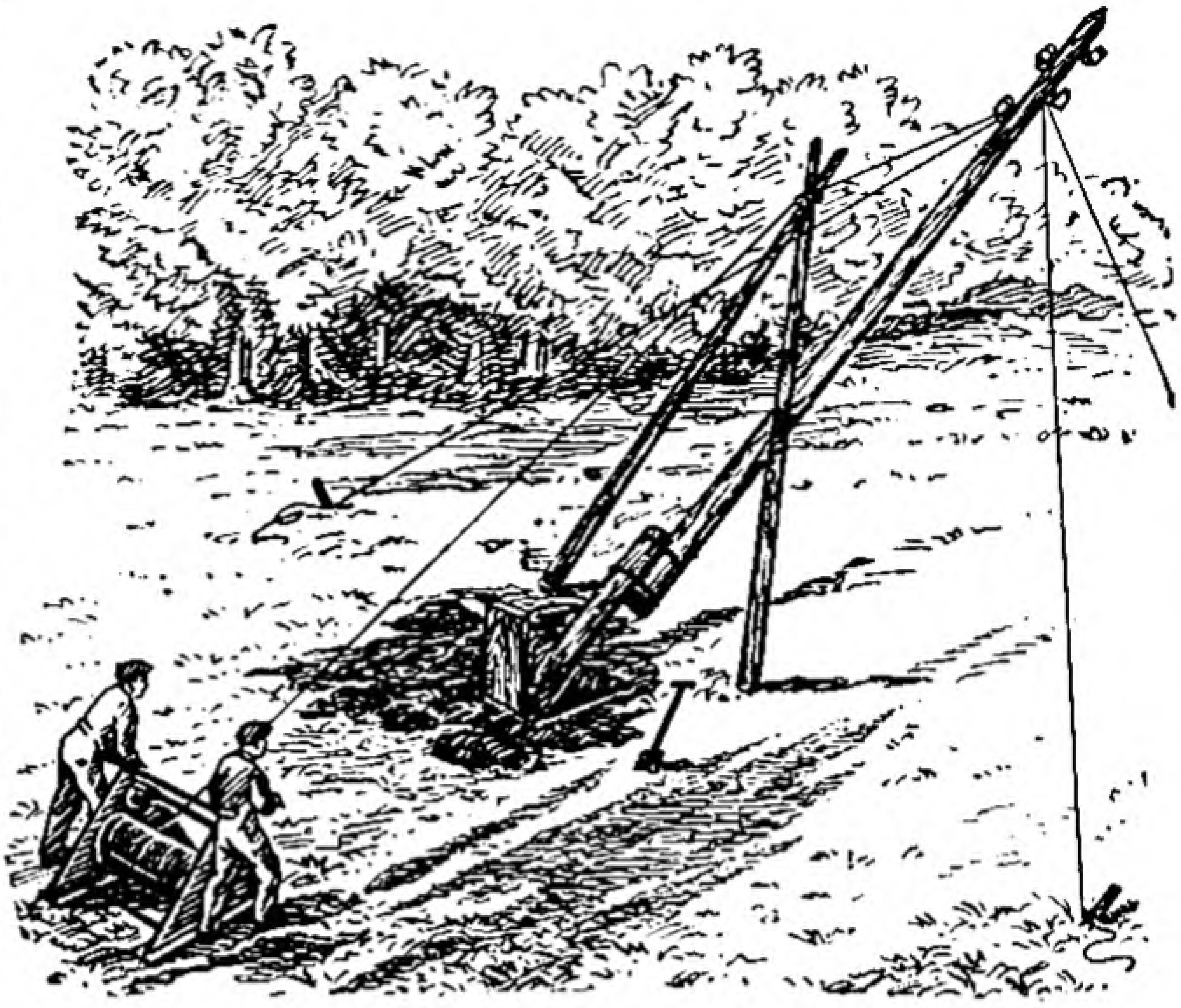


Fig. 219. Pole lifting with A-frame pole.

3. Line Insulators and Their Installation

To secure the wires on overhead power lines such as those with which we are concerned here, use is made of type ШЛН (ShLN) and АИК (AIK) pin insulators (see Table 2). Where a tap-off line must be connected, type ШО (ShO) special multi-groove-neck pin insulators are installed (Fig. 220).

In fitting the above types of pin insulators on their gooseneck hooks or straight pins, the ends of the hooks and pins are first served with a wrapping of hemp impregnated with an anti-rot compound, or tow dipped in red lead mixed with boiled linseed oil.

When three-wire lines are installed, the insulators are arranged on each pole in a triangular fashion; four-wire lines are installed with the insulators staggered on each pole, two insulators on each side of the pole. A vertical distance of at least 400 mm is observed between each wire. It is good practice to fix the insulators on the poles before the latter are lifted and set. Holes for

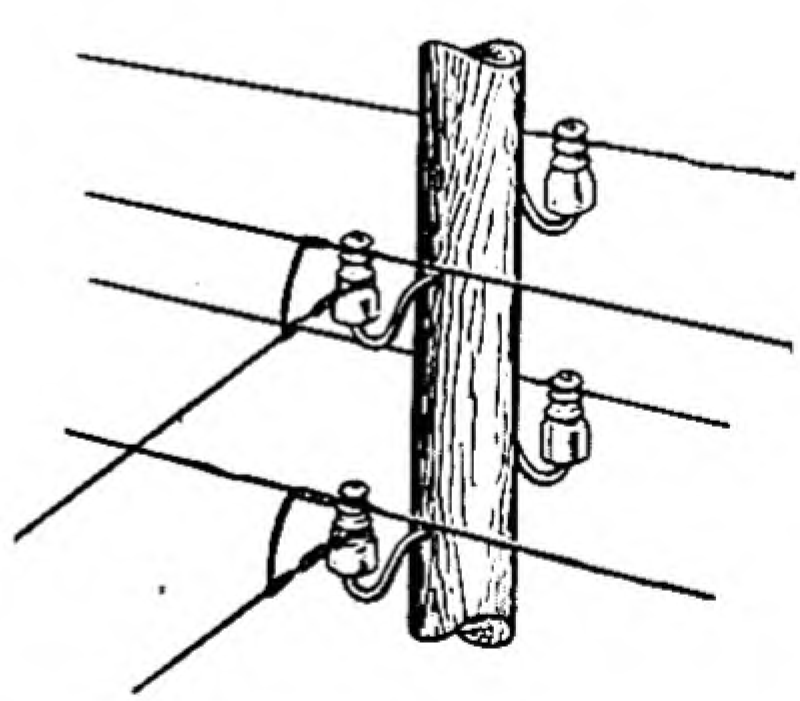


Fig. 220. Type ШО (ShO) multi-groove-neck insulators at a line tap-off.

fixing hooks are bored with a tapered gimlet having a diameter 3 to 4 mm less than that of the threaded hook shank. The fit will then be tight when the hook is screwed into the bored hole.

4. Line Wires and Their Installation

As a rule, low-voltage overhead lines are installed with bare wires, the minimum diameter or sizes of which (to provide adequate mechanical strength) are:

a) for steel wire—a diameter not less than 2.75 mm;

b) for aluminium wire—a size not less than 16 sq mm;

c) for copper wire—a size not less than 6 sq mm.

Wire for overhead line stringing is supplied either in coils or reeled on drums. Wire brought in and laid out along a line route in coils requires unreeling and stringing from vertical-axis unreeling stands.

Wire brought in reeled on drums is unreeled from the drums after raising them on an axle with drum jacks (Fig. 221*a*).

As a line wire is unreeled it is laid on the hooks supporting the insulators with hook poles. If the line has a neutral conductor it must be strung from the lowest insulators.

A very convenient way of unreeling, stringing and tensioning of the line wires is to use installer's sheaves temporarily hung from the insulator hooks (Fig. 221*b*).

Fig. 221. Unreeling and stringing wires on a line:

a — drum of wire raised on drum jacks, *b*—installer's sheave hung from insulator hook.

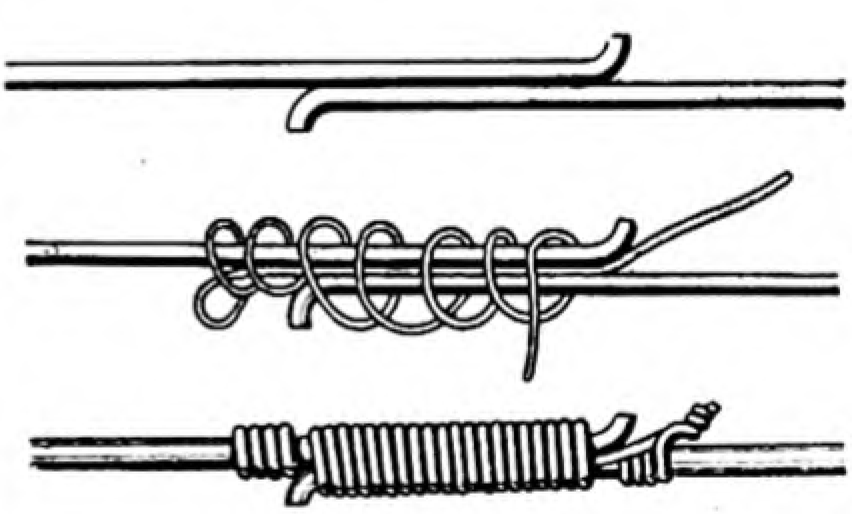


Fig. 222. Solid wire splicing by banding with wrapping wire.

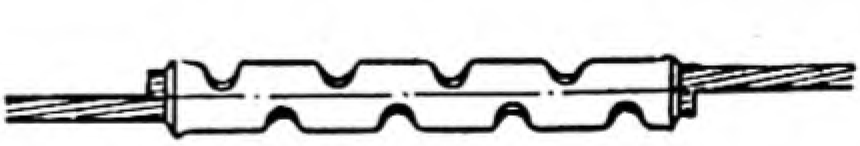


Fig. 223. Wire spliced with an oval-shaped connector tube.

The line wires, where they require jointing, are spliced by making a wrap joint or using an oval-shaped tube connector.

Solid-strand wires are, as a rule, jointed by banding with a wrapping wire (Fig. 222). Both wires must be of the same material—a copper wire to be jointed with a copper wrapping wire, a steel wire—with a steel wire of 1 to 1.5 mm diameter. The joint is completed by soldering it with ПОС-30 (POS-30) tin-lead solder. The ways to splice multi-strand wires are illustrated in Fig. 223, where an oval-shaped tube connector is used, and in Fig. 224 where the steps followed in making a wrap splice are shown.

Oval-shaped tube connectors for copper, aluminium and steel wires are made, respectively, of copper, aluminium or steel tubing. The joints are made by inserting the wires at both ends (see Fig. 223) and compressing them with special indenting tongs.

When the wires are small in size and the spans are short, the line wire is tensioned by hand, but when the sizes of the wires are great and the spans long, the tensioning is done with multi-pulley tackle blocks (Fig. 225).

Line wire is tied to insulators usually with 1 to 1.5 mm diameter tie wire of the same material as the line wire.

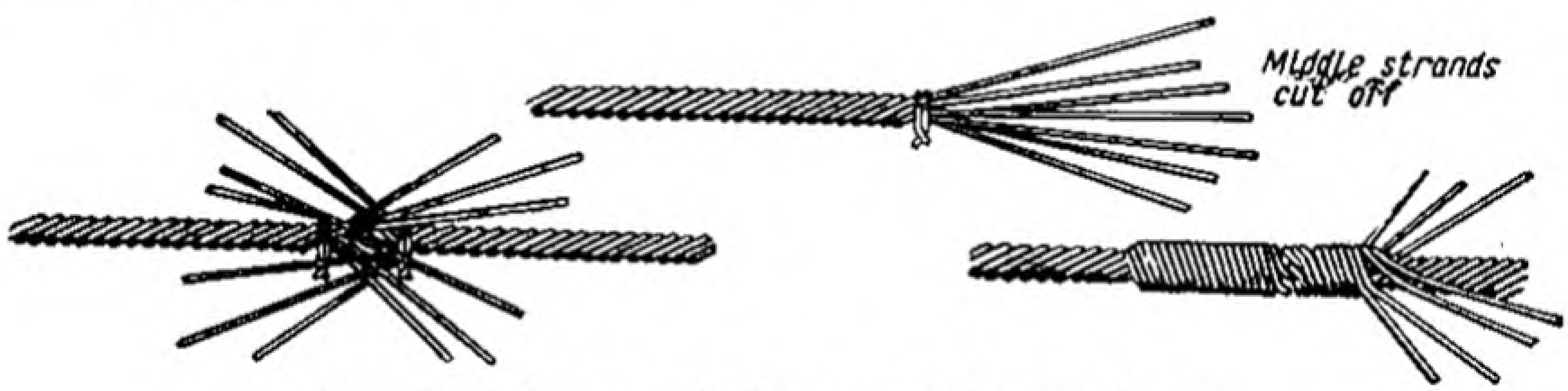


Fig. 224. Wrap splicing a multi-strand wire.

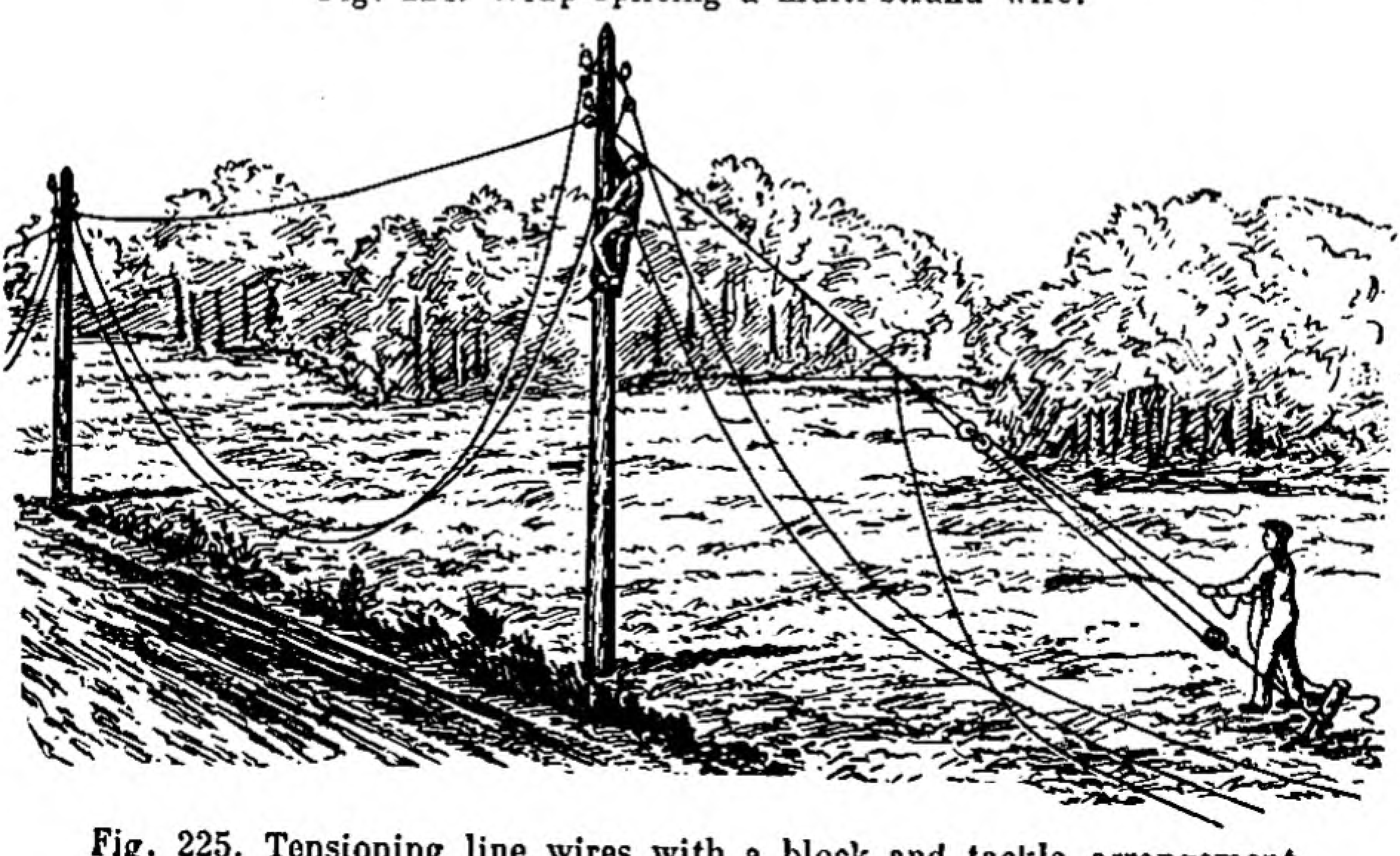


Fig. 225. Tensioning line wires with a block and tackle arrangement.

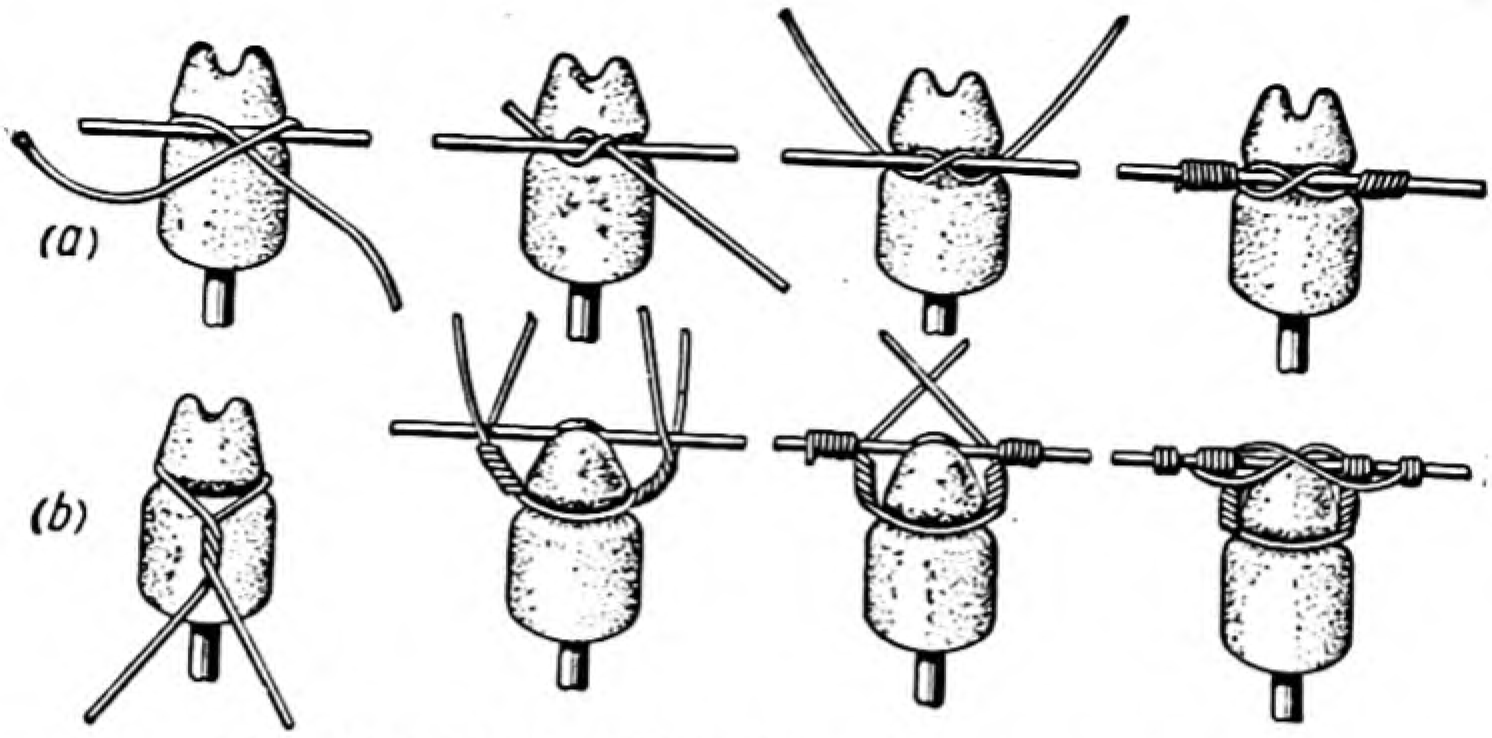


Fig. 226. Method of tying wires to insulators:
a—side tie, b—head tie.

Depending upon where the wire is to be tied, on the head or at the neck of the insulator, a head or side tie of different type is used (Fig. 226).

The side tie is made with the wire placed on the insulator on the side facing the pole, with the exception of the insulators on angle poles where the wire is arranged on the external sides of the angle of turn in line route. On angle and terminal poles the wires must be tied to the insulators only at the neck groove. On terminal poles the wires can be dead-ended by wire-clamp looping or by making a wrap-jointed dead-end loop (Fig. 227).

Linemen climb the poles and install the wires wearing steel climbing irons which they strap to their feet. They also wear a lineman's belt provided with a chain by which they can support and safeguard themselves when working on a pole (Fig. 228).

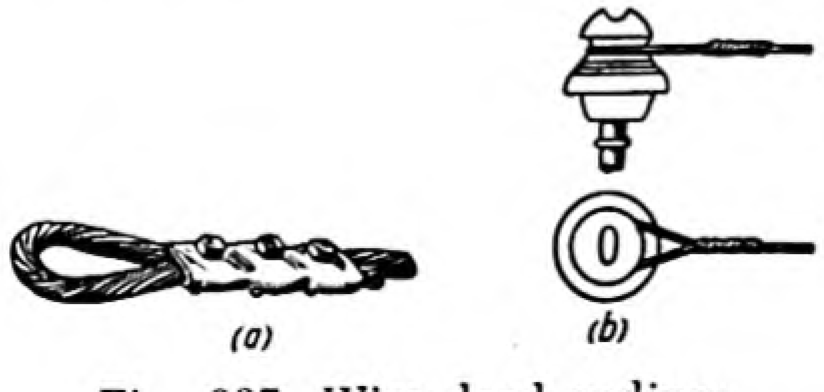


Fig. 227. Wire dead ending:
a—by wire-clamp looping, b—by wrap-joint looping.

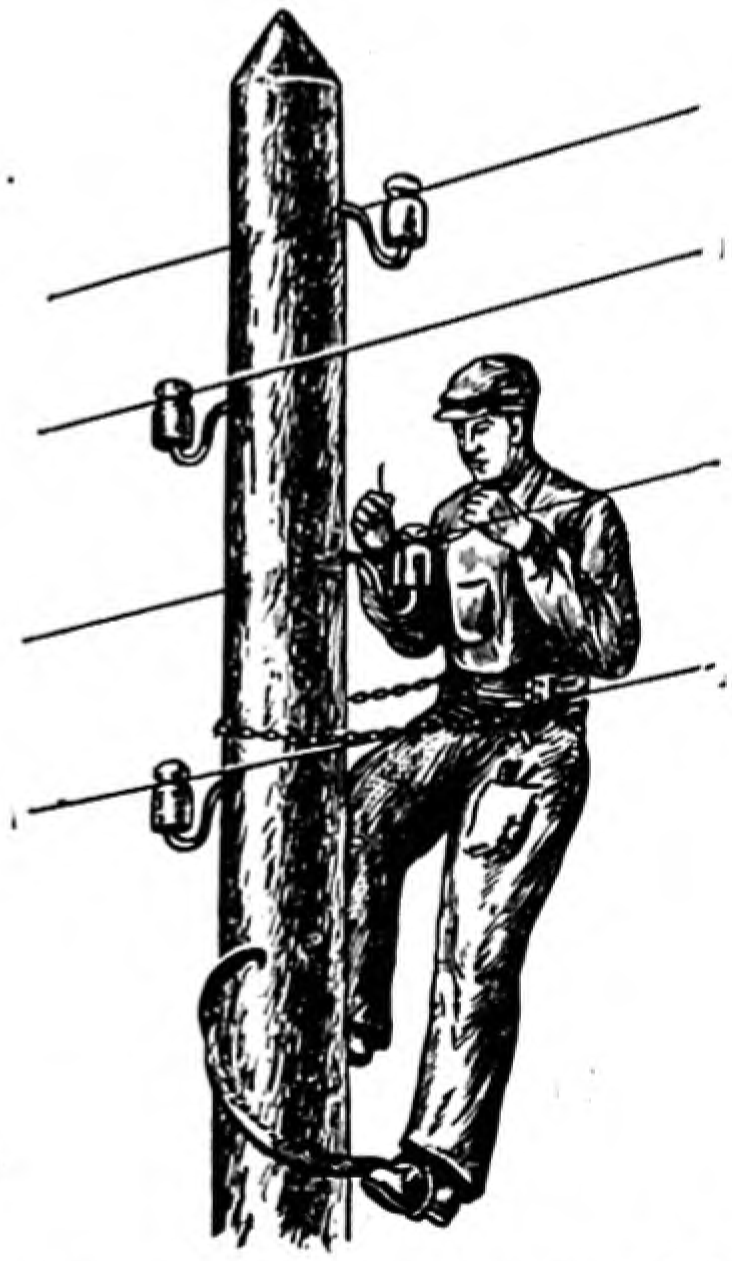


Fig. 228. How lineman uses his climbing irons and safety belt.

5. *Rules for Safety When Erecting Overhead Lines*

Linemen who work on poles must firmly know the command signals used in carrying out all the line-work operations.

Never leave an axe sticking in the top of a pole or in any other part of a pole assembly.

Poles may be climbed only after they have been set in their holes and the backfilling and tamping have been fully completed.

Unreeling of wires and wire rope must be done with the hands always protected by mittens.

Never work on a pole on the inner side of a turn in direction of the line route.

Linemen working on poles must always wear their lineman's safety belt and loop the belt chain round the pole and hook it to their belt.

No work shall be performed on overhead lines during thunderstorms.

Part Four

HIGH-VOLTAGE SUBSTATIONS

Chapter VII

FEATURES AND EQUIPMENT OF TRANSFORMER SUBSTATIONS IN INDUSTRIAL UNDERTAKINGS

1. Substation Classification

Substations in industrial undertakings are classified according to their purpose, kind of construction or design, and their location.

According to purpose substations may be subdivided into:

1) *main step-down substations* (MSS) serving to receive supply from some power system or a local power station and lower its voltage for distribution over the territory of the industrial undertaking or some given district;

2) *central distribution substations* (CDS) likewise serving to receive electric power and distribute it over the territory of an industrial undertaking at the same voltage (without voltage transformation);

3) *distribution substations* (DS) serving to receive electric power from a MSS and distribute it over the territory of an industrial undertaking at the same voltage. Large industrial undertakings may have several DS's and one CDS;

4) *shop transformer substations* (TS) serving to receive power at 6 or 10 kv from a DS (or in some cases from a CDS) and transform it to 500, 380 or 220-volt supply for distribution to one or several shops;

5) *special substations*, for example, electric furnace substations (EFS), power conversion substations (PCS).

According to design, substations may be:

1) of the *indoor* type, with the apparatus installed within special substation buildings and usually for a voltage of 6 or 10 kv (CDS's, DS's and TS's are mainly of this type);

2) of the *outdoor* type, which are erected in the open, usually for voltages from 35 kv upward (a MSS, for example).

Depending on their location in the territory of an industrial undertaking, substations maybe called:

1) separately standing (generally the MSS's, CDS's);

2) lean-to, built either as premises fully contained and placed against a shop building,

or partially built into a shop building so that the high-voltage apparatus is outside the building and the low-voltage equipment is inside the building (DS, TS);

3) in-shop, substations installed directly within a shop or department (TS).

2. *Main Connection Schemes*

The reception and further distribution of electric power in substations and switchgear installations is accomplished by means of their main bus-bars to which the apparatus is connected according to some given main circuit scheme.

To interconnect high-voltage power lines, overhead or cable, with the main bus-bars in the substations, special types of apparatus are used; isolators (or disconnecting switches), circuit breakers, instrument transformers, etc.

Connections may be classed as: incoming (power feeder connections), tie (lines interconnecting two substations or switchgear installations, each of which is supplied through its own incoming feeder connection), outgoing (feeder connections for supplying other subsequent switchgear installations or substations), power transformer (connections made in a given substation), voltage transformer (connections for control and metering).

The main connections diagram drawn for a substation shows how all the circuit arrangements are made with its main bus-bars.

All the electrical connections of a substation or switchgear installation can be represented on a single-line diagram.*

On the single-line diagrams standard graphical symbols represent the main elements of the installation: circuit breakers, isolators, fuses, instrument transformers, etc. These diagrams also show how the main elements are interconnected with one another.

* To simplify representation and facilitate reading, the main connections diagrams for three-phase circuits are drawn only for the middle phase, it being understood that all the phases are connected identically.

Graphical Symbols for Representing Several Types of Apparatus and Circuit Elements on Substation Main Connections Diagrams

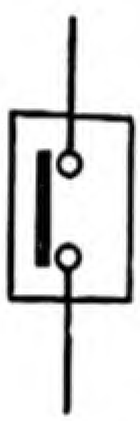

Bus-bars


Tap-off from bus-bars

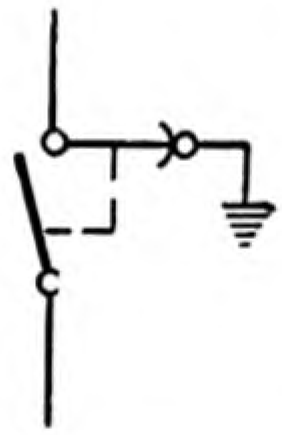

Cable termination

Isolator (or disconnecting switch)

Load-interrupter switch incorporating arc-extinguishing device

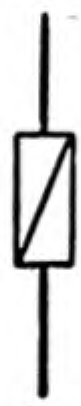


Circuit breaker



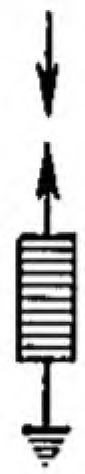
Single-pole isolator with earthing knife and mechanical interlock

Plug-in connection in withdrawable contact arrangements and in apparatus

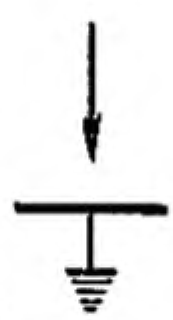


Fuse

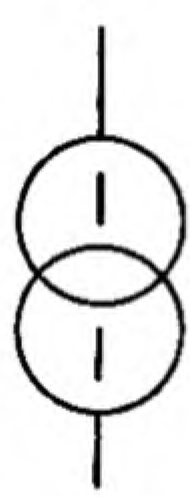
Lightning arrestor (general symbol)



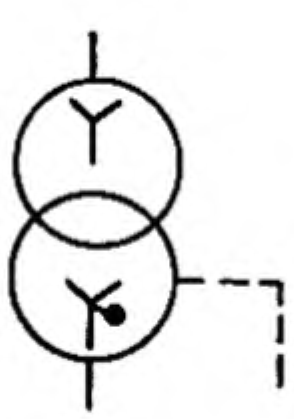
Valve-type lightning arrestor



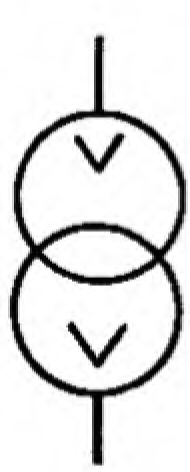
Gap fuse (arrestor)



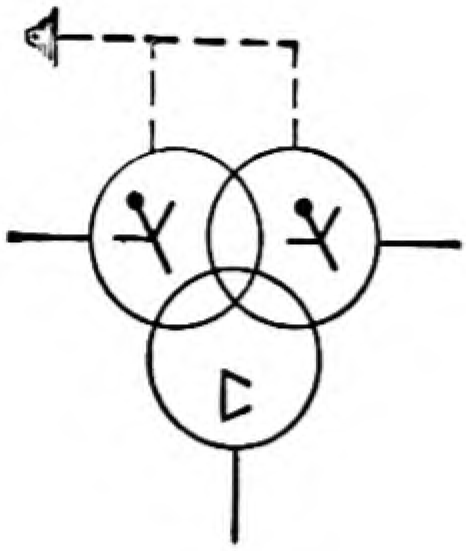
Single-phase transformer



Three-phase transformer with star-star connected windings and a brought-out neutral (from one winding)



Two single-phase voltage transformers in open-delta (v) connection



Three-phase, three-winding voltage transformer having two star-connected windings, each with the neutral brought out and earthed, and one winding connected as an openeddelta

Current transformer with single secondary winding

Current transformer with two secondary windings

Main connections diagrams showing the arrangements of various typical connections and the simplest of substation schemes for industrial undertakings are given in Figs 229,. 230 and 231.

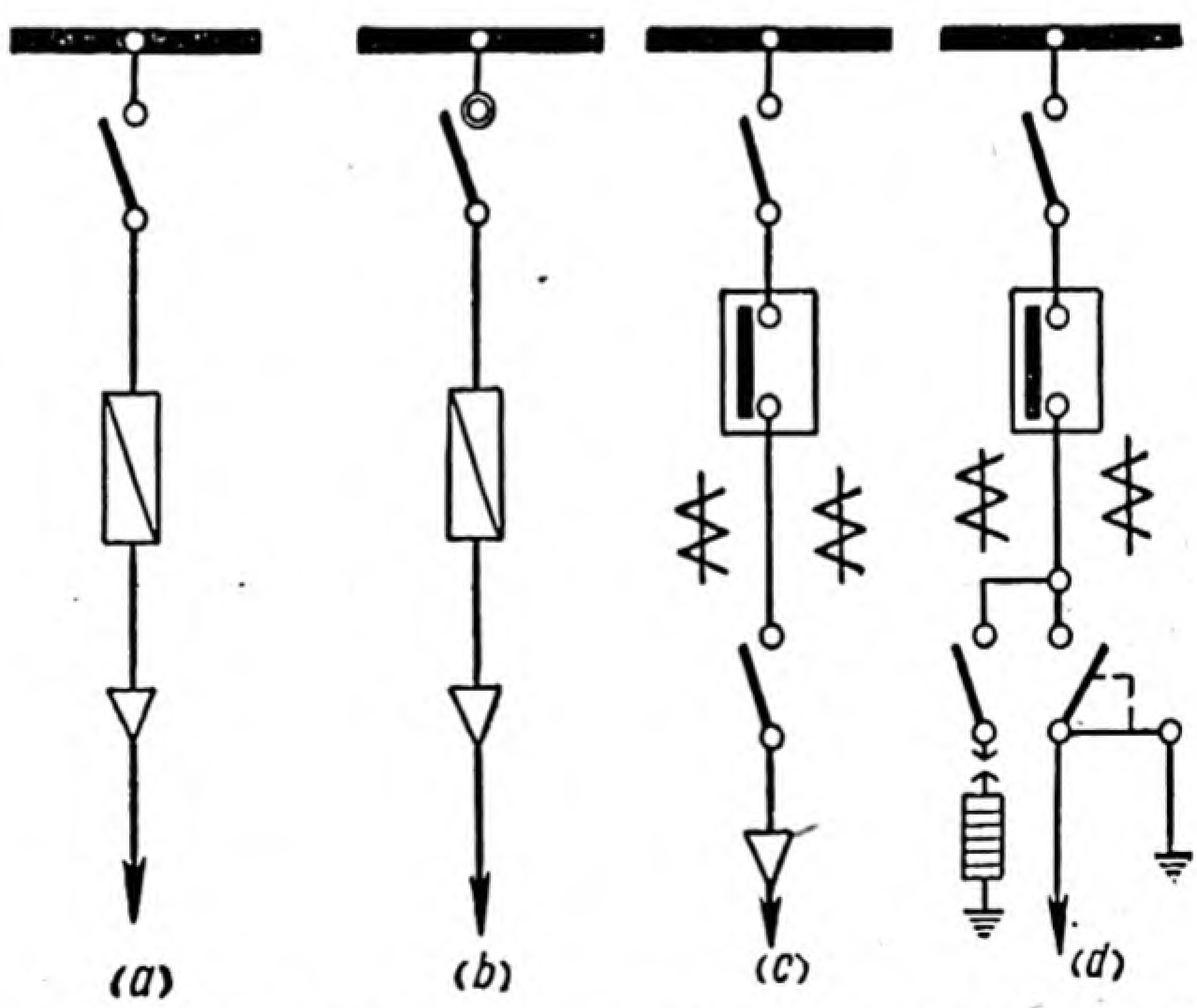


Fig. 229. Typical kinds of connections to main bus-bars in 6- and 10-kv switchgear installations:

a—connection with isolator and fuse, *b*—connection with load-interrupter switch and fuse, *c*—connection with bus isolator, circuit breaker and line isolator, *d*—connection with bus isolator, circuit breaker and a line isolator having earthing knives, the main connection also incorporating a valve-type lightning arrestor connected through an isolator.

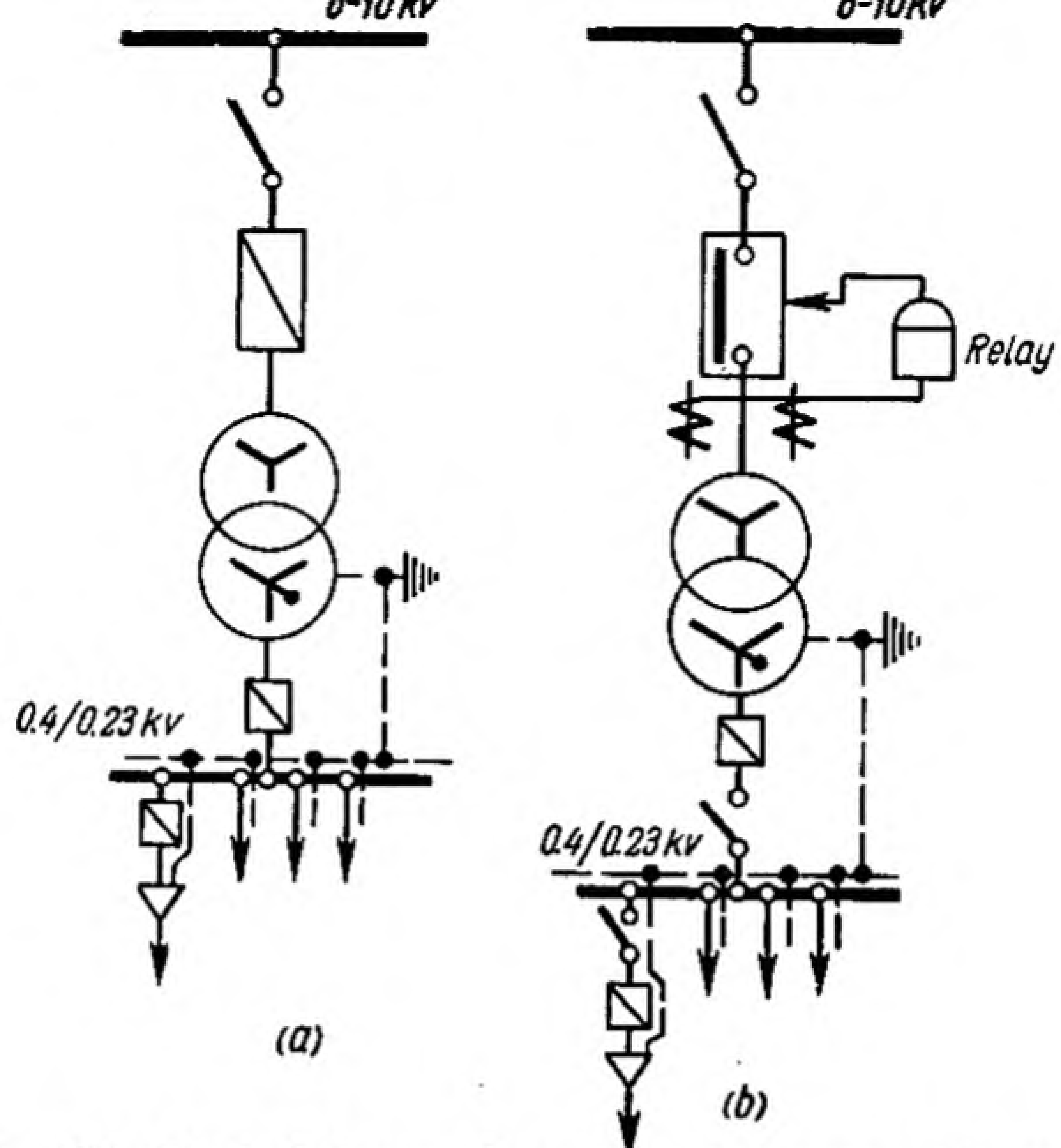


Fig. 230. Typical forms of power transformer main connections:

a—transformers with ratings up to 180 kva, *b*—transformers with ratings over 180 kva.

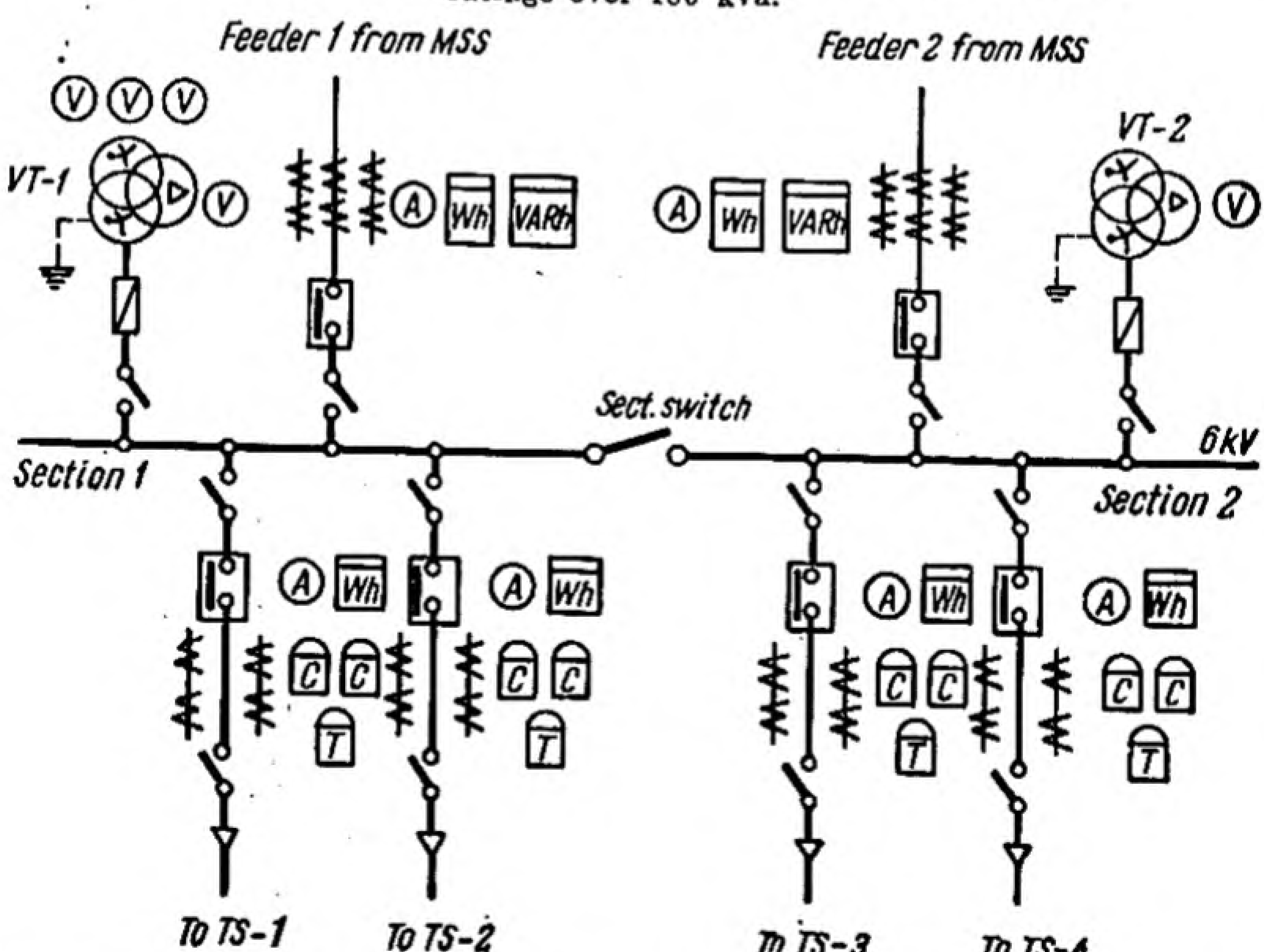


Fig. 231. Full single-line main connections diagram of a 6-kv switchgear installation showing voltmeters (V), voltage transformers (VT), ammeters (A), active and reactive power meters (Wh, VARh), overcurrent relays (C) and time-lag relays (T).

3. Current-Carrying Parts and Main Apparatus of 6- and 10-kv Indoor Substations and Switchgear Installations

Main Bus-Bars

Within any given substation or distributing switchgear installation the electric power is transmitted and distributed through the main bus-bars.

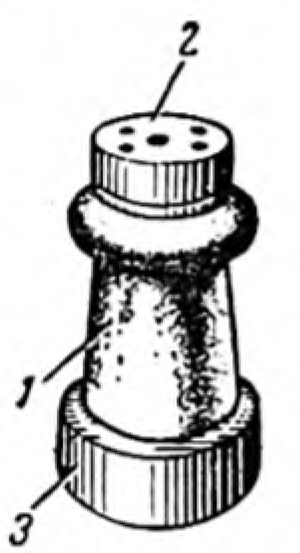


Fig. 232. Post insulator type OA-10пр (OA-10pr).

Main bus-bars are assemblies consisting of the bus-bars, the insulators on which they are installed, the metalwork to which the insulators are attached and the hardware and fixing accessories used for securing the bus-bars on the insulators and for attaching the insulators to the support metalwork (bus-bar clamps, bolts, nuts, washers).

The bus-bars used for 6- and 10-kv indoor switchgear installations take the form of bare, rectangular cross-section bars, usually of aluminium (less frequently, of copper) 5 to 6 metres long.

The most frequently used sizes of bus-bars are: 40×4 mm (160 sq mm), 40×5 mm (200 sq mm), 50×5 mm (250 sq mm), 50×6 mm (300 sq mm), 60×8 mm (480 sq mm), 80×8 mm (640 sq mm) and 100×10 mm (1,000 sq mm).

The porcelain insulators used in switchgear installations are of the post and bushing (through) type. They serve as the supports and insulation of the bus-bars.

A post insulator (Fig. 232) consists of porcelain body *1*, cast iron cap *2* and flanged cast iron base *3*.

The hole in the cap is threaded to permit the bus-bars to be either directly bolted to the cap or be fixed by means of a bus-bar clamp.

Post insulators are available with round, oval and square flanged bases for fixing, respectively, with the aid of one, two or four bolts. Each base, in addition, also has an earthing bolt.

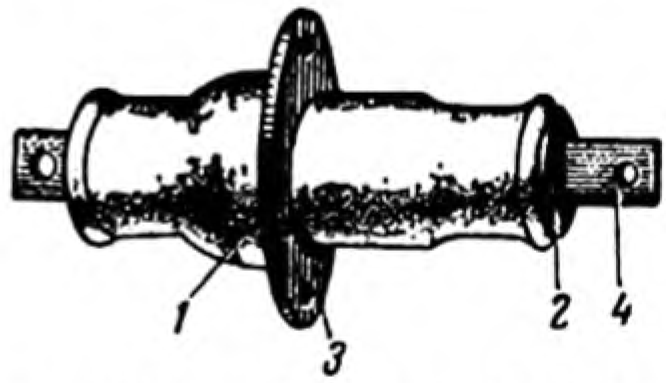


Fig. 233. Bushing type ПА-6/400 (PA-6/400).

A bushing or through insulator (Fig. 233) consists of porcelain-shell body *1*, upper and lower locating washers *2* serving to fix the position of current-carrying bus-bar or rod *4* in the shell, and mounting flange *3* with holes drilled for fixing bolts and supplied with an earthing bolt. For current ra-

Several Main Types of Porcelain Insulators and Bushings Used for 6- and 10-kv Indoor Switchgear Installations

Type designation	Rated voltage, kv	Breaking bending load, kg	Rated current, a
ОА-6 ов (OA-6 ov) or ОА-6 кр (OA-6 kr) . .	6	375	—
ОБ-6 ов (OB-6 ov) or ОБ-6 кр (OB-6 kr) . .	6	750	—
ОА-10 ов (OA-10 ov) or ОА-10 кр (OA-10 kr)	10	375	—
ОБ-10 ов (OB-10 ov) or ОБ-10 кр (OB-10 kr)	10	750	—
ОВ-10 кв (OV-10 kv)	10	1,250	—
ОД-10 кв (OD-10 kv)	10	2,000	—
ПА-6/200 (PA-6/200)	6	375	200
ПА-6/400 (PA-6/400)	6	375	400
ПБ-6/600 (PB-6/600)	6	750	600
ПВ-6/2000 (PV-6/2000)	6	1,250	2,000
ПБ-10/600 (PB-10/600)	10	750	600
ПВ-10/2000 (PV-10/2000)	10	1,250	2,000

tings over 2,000 amp, bushings are not fitted with either current-carrying bus-bar or rod parts. They are designed to permit the main bus-bars to be passed directly through them.

Insulators are rated for a nominal working voltage (6, 10 and 35 kv) and a given mechanical strength based on the breaking force in bending. Four mechanical strength groups have been established: А, Б, В and Д (A, B, V and D). They correspond to the breaking loads of 375, 750, 1,250 and 2,000 kg, respectively. In addition, bushings are also rated for the nominal current-carrying capacity of their bus-bars or rods.

The type and characteristics of post insulators are indicated by their type designations. For example: ОА-10ов (OA-10ov) indicates a post insulator of A-group strength rated for 10 kv and fitted with an oval-flanged base; ПБ-6/600 (PB-6/600) indicates a bushing of B-group strength rated for 6 kv and 600 amp. Several of the porcelain substation types of insulators used in 6- and 10-kv indoor installations are listed in Table 27.

For identifying each phase of the main bus-bars and to protect them against corrosion, improve their heat dissipating capacity and give the entire installation a neat finished appearance, each phase of the bus-bars is coated with paint according to a fixed colour code.

The following colours are used for coding the bus-bars:

first phase (A)—yellow;
second phase (B)—green;
third phase (C)—red.

The order of arranging bus-bars according to their colour code is shown in Table 28.

7*

Table 28

Arrangement of Buses According to Colour in Main Bus-Bar Assemblies

Main bus-bars in horizontal runs one above the other	Main bus-bars in horizontal runs at the same elevation	Vertical runs of bus-bars
Upper R	*Rear* R	R G Y
Middle G	*Middle* G	
Lower Y	*Front* Y	*Left* *Middle* *Right*

It is also permissible to use a reversed order of colouring bus-bars. The middle bus-bar, however, must always be painted green.

Isolators

An isolator (or disconnecting switch) is designed to open some given part of a power circuit after the load has been switched off by a circuit breaker. Consequently, isolators serve only for preventing the voltage from being applied to some given bus section in a switchgear installation or to one or another piece of apparatus in the installation, and, since isolators have an open contact system, they create a visible break in the electric circuit.

In separate cases isolators can be used as a circuit-breaking device, but their use for this purpose is strictly limited by definite conditions, for example, the power level of the given circuit.

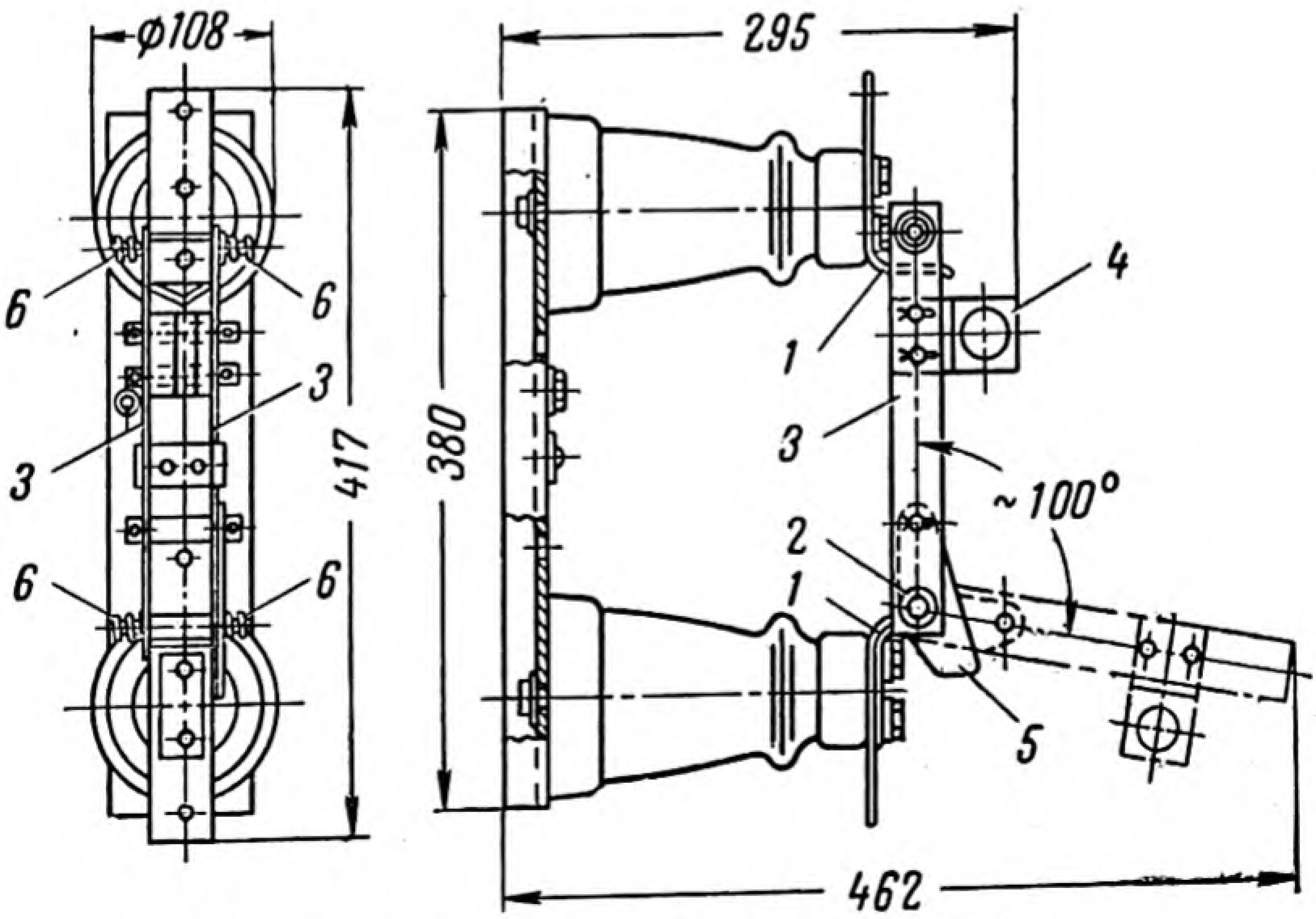


Fig. 234. Type PBO (RVO) single-pole isolator.

In 6- and 10-kv circuits in particular, the isolator can be used to interrupt the no-load current of power transformers with ratings up to 750 kva.

Isolators are available in single-pole and three-pole versions. Fig. 234 shows a single-pole indoor isolator rated for 10 kv and 400 amp. The contact knife pivoted on pin *2* consists of two flat-bar arms *3* which wedge down over fixed contact post *1*. Springs *6* serve to create the necessary pressure between the contacting surfaces. Stop plate *5* limits the distance to which the isolator can be opened.

Single-pole isolators are opened and closed manually, an isolator-operating hook pole made of an insulating material being used for this purpose. To do opening and closing, the pole tip is provided with a finger which can enter eye lug *4*.

Fig. 235 shows a three-pole indoor isolator rated for 10 kv and 400 amp. The contacts are made in the same way as on a single-pole isolator. Knives *5* are actuated by rocking porce-

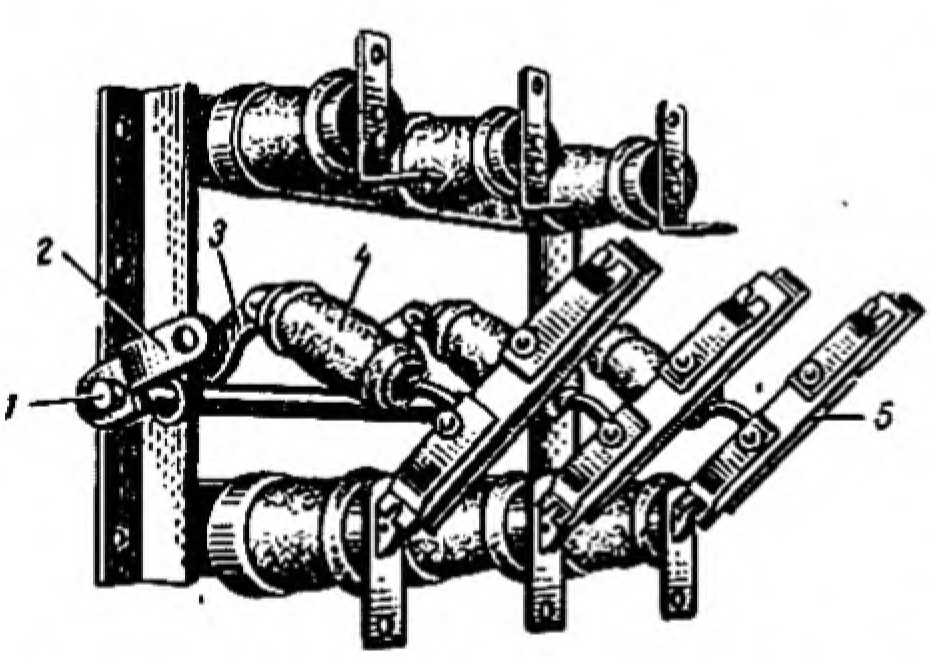


Fig. 235. Type РЛВ-III (RLV-III) three-pole isolator.

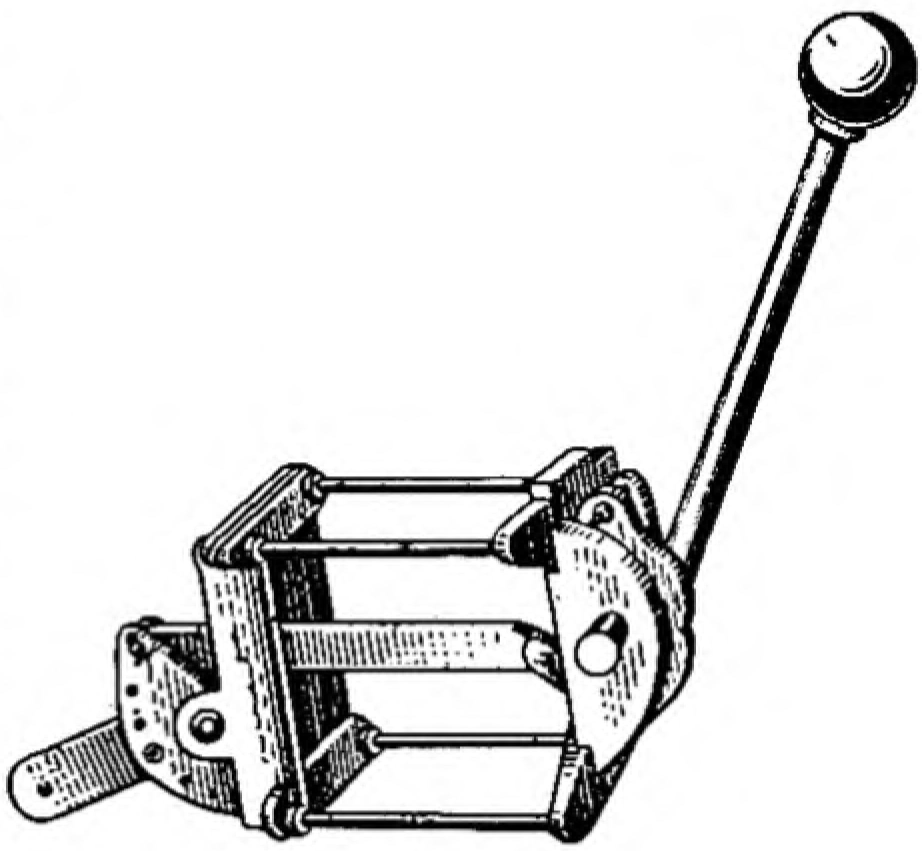


Fig. 236. Type ПР (PR) lever-arm manual operating mechanism for three-pole isolators.

lain-insulator links *4* pivot pinned to the knife blades and to levers *3* fixed on the common actuating shaft *1*.

Three-pole isolators are usually closed and opened by a special manual operating mechanism, either type ПР (PR) (Fig. 236), or type ПРМ (PRM). These mechanisms are connected by means of a steel-pipe tie rod (see Fig. 279) to the isolator actuating lever *2* shown in Fig. 235.

Common types of isolators for indoor installation are: the РВО (RVO) single-pole isolators rated for 6 and 10 kv and for 400 to 600 amperes, and the РЛВ-III (RLV-III) three-pole isolators rated for 6 and 10 kv and for 1,000 to 3,000 amp.

Examples of the full type designations of the above isolators are: РВО-6/400 (RVO-6/400) and РЛВ-III-10/1000 (RLV-III-10/1000).

The letters and numbers in the isolator type designations have the following meanings: P (R)—isolators, B (V)—for indoor installation, O—single-pole, III—three-pole, Л (L)—for line current circuits. The numbers of the fractional designation give the kv voltage rating in the numerator and the current rating in the denominator.

Circuit Breakers

Under normal operating conditions circuit breakers serve to close and open circuits at their usual working loads. When short circuits occur, or an overload appears, they also automatically trip out the faulted circuit, automatic operation being achieved if protective relays have been incorporated. Since the contacts in circuit breakers draw an electric arc when they interrupt the load currents, they are designed with arc-extinguishing or arc-control devices.

In indoor switchgear installations the oil-filled and the hard-gas types of circuit breakers are mainly employed.

Oil-filled circuit breakers can be divided into two groups: a group in which a large volume of oil is used (tank or bulk-oil breakers) and a group using a small volume of oil (oil-minimum breakers).

The single-tank type ВМБ-10 (VMB-10) oil circuit breaker, rated for 10 kv (Fig. 237), has a round, weld-fabricated steel tank *1*, filled with transformer oil. On this circuit breaker, top plate *7* has six terminal

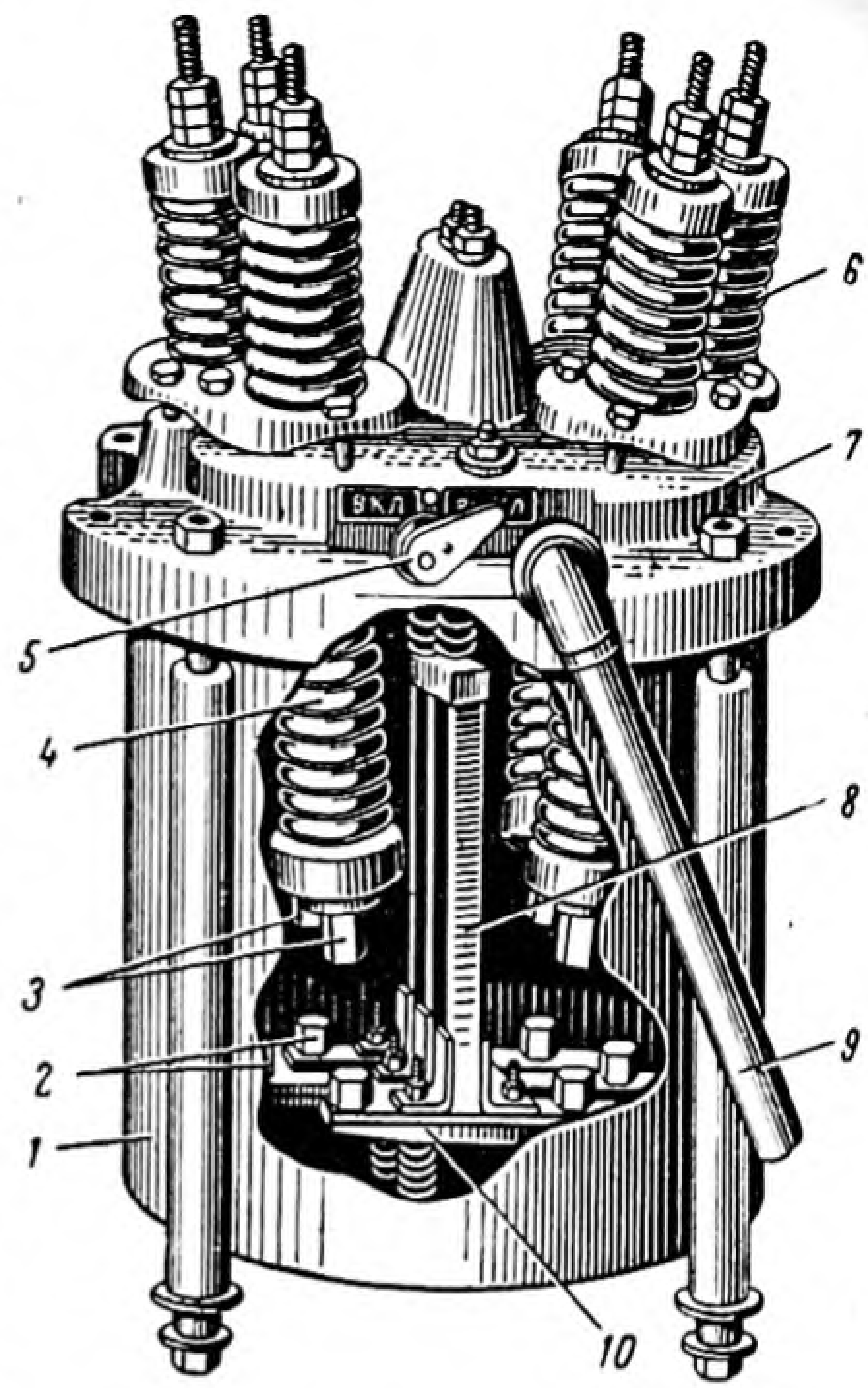


Fig. 237. Type ВМБ-10 (VMB-10) single-tank oil circuit breaker:
1—tank, *2*—moving contacts, *3*—stationary contacts, *4*—opening springs, *5*—position indicator, *6*—terminal bushings, *7*—top plate, *8*—insulating lift rod, *9*—gas vent pipe, *10*—cross-arm.

bushings *6* mounted in it on one centre-line circle. On the oil-submerged ends of the terminal bushings the current-carrying rods are fitted with stationary contacts *3*. Moving contacts *2* are arranged on cross-arm *10* which, when the breaker is closed, is caused to rise by insulating lift rod *8* and thus bring contact *2* up against contact *3*.

Opening of the circuit breaker occurs with reverse action during which an electric arc is drawn between the stationary

and moving contacts. The high temperature of the arc causes the surrounding oil to decompose and liberate gases which form a gas bubble around the arc and contain up to 70 per cent of hydrogen. The latter, due to its high heat conducting capacity, actively cools the arc and thereby helps to extinguish it quickly.

The 10-kv ВМГ-133 (VMG-133) oil-minimum circuit breaker (Fig. 238) has three steel, copper-brazed chambers (pots) *1* fitted with oil gauges *14* and gas discharge slits.

The pots are secured to frame *4*

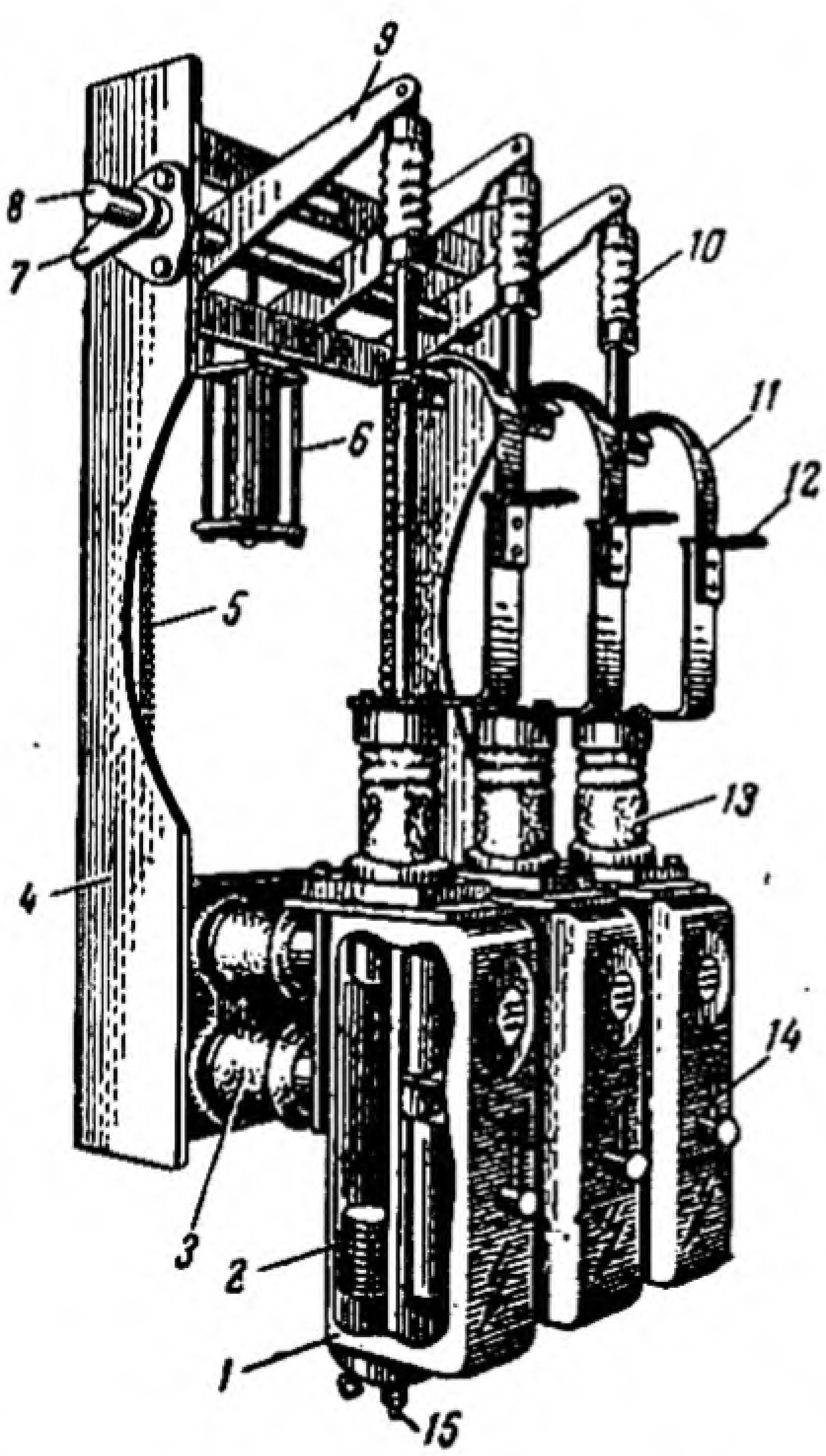


Fig. 238. Type ВМГ-133 (VMG-133) oil-minimum circuit breaker.

by means of support insulators *3*. Fitted inside each pot is a stationary cluster contact incorporating a tang-ended terminal brought out for attachment of bus-bar leads. The pots of this circuit breaker are always under voltage (alive).

The moving contact, in the form of a round rod pivot pinned to porcelain tie link *10*, passes into the pot through insulator bushing *13*. Current led in from the bus-bar system to terminal *12*, through flexible lead *11*, is passed to the moving contact down which it flows inside the pot to the stationary cluster contact for lead-out by terminal *15*.

Porcelain tie links *10* are pivot pinned to double-arm levers *9* welded on shaft *8*. The latter, by means of actuating lever *7* fitted on its end, is connected to a circuit-breaker operating mechanism. When the circuit breaker is closed, opening springs *5*, attached, at the bottom, to the breaker frame and, at the top, to the short arms of the left and right levers *9*, become tensioned. These opening springs ensure swift rise of the moving contacts and quick breaking of the circuit when the circuit breaker is tripped open.

The arc created the instant the circuit is broken is intensely extinguished by the gases liberated from the oil by the high temperature of the arc.

Under the control of extinguishing chamber *2* and due to its design, the gases travel transverse to the arc when large currents are interrupted and

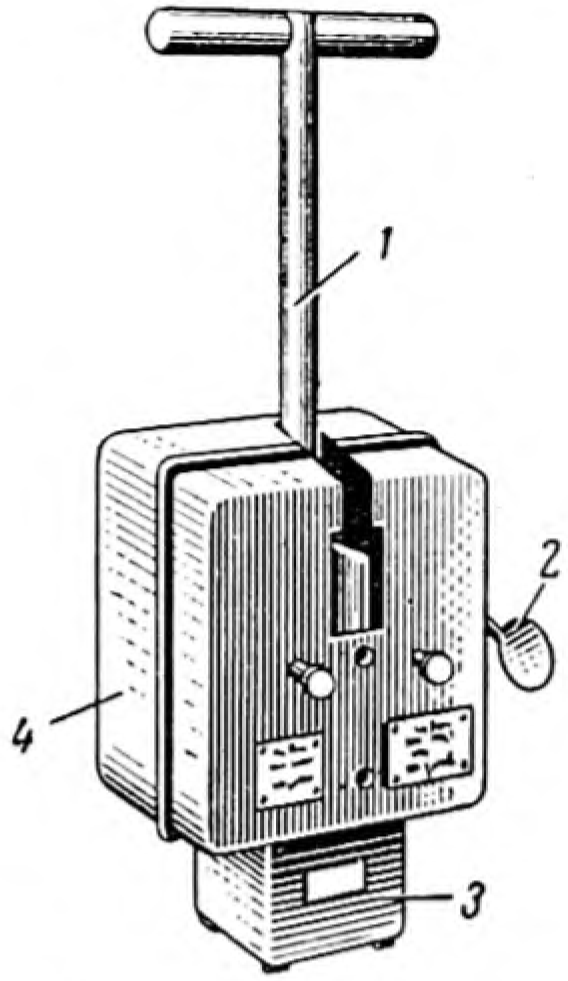


Fig. 239. Type ПРБА (PRBA) lever-arm operating mechanism with automatic trip-out.

along the arc when small currents are interrupted, creating in the first case a cross blast, and, in the second case, a longitudinal blast.

To absorb the shock in the mechanism when opening occurs, the circuit breaker is provided with oil buffer *6* arranged so that its piston is met by the short arm of middle lever *9*. This same arm comes against a spring buffer (not shown in Fig. 238) when the circuit breaker is closed.

To operate these circuit breakers, use is made of different kinds of operating mechanisms of both the manually-operated and the remote-controlled type.

A widely used manual type of operating mechanism is the ПРБА (PRBA) mechanism — meaning operating mechanism, lever-arm operated, with operating indicator and automatic trip-out (Fig. 239).

This operating mechanism permits the circuit breaker to be closed and opened by hand with the aid of its operating lever *1* interlinked with the mechanism parts housed in case-frame *4*. At the bottom part of the frame, box *3* houses relays or simple electromagnetic coils by means of which the circuit breaker can be automatically tripped open. When automatic tripping occurs, the circuit breaker opens, but the operating mechanism remains in the "closed" position. That opening has taken place is indicated by operation-indicator target *2* which takes up a horizontal position. Coupling of the operating mechanism to the circuit-breaker actuating lever is accomplished with a steel-pipe tie rod.

For remote control of these circuit breakers type ПС-10 (PS-10) solenoid operating mechanisms are generally used (see Fig. 280).

Load-Interrupter Switches

Load-interrupter switches are designed to close and open high-voltage circuits under normal operating conditions (at normal load).

Fig. 240 shows a type ВНП-16 (VNP-16) load interrupter which includes high-voltage fuses. The arc-extinguishing device of this load interrupter is made in the form of a split, moulded-plastic chute fitted with organic glass inserts. This chute surrounds

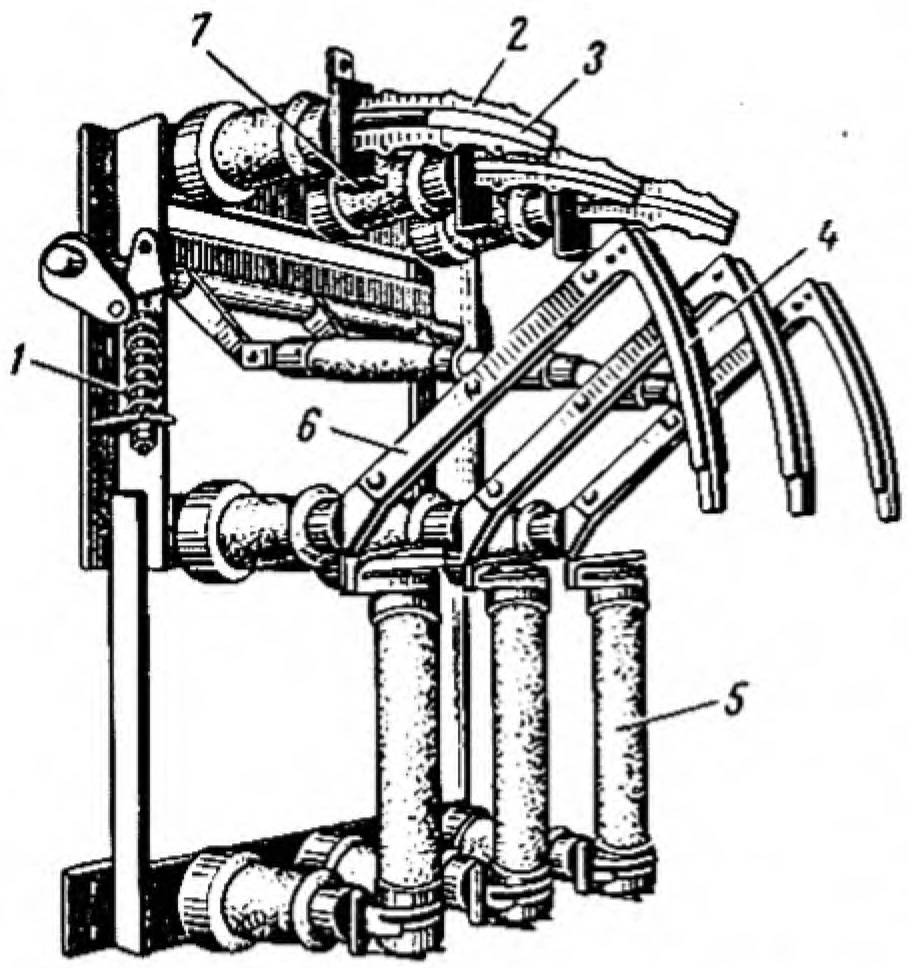


Fig. 240. Type ВНП-16 (VNP-16), load-interrupter switch:
1—opening springs, *2*—arc-extinguishing chute, *3*—plastic glass insert, *4*—knife of arc-extinguishing system, *5*—fuse, *6* and *7*—working contacts.

set of power fuses *5* which protects the connected circuit against overload currents and short circuits. These switches, when rated for 10 kv, are available for a working current of 200 amperes. Their maximum current-breaking capacity is 400 amp.

Fuses

High-voltage power circuits with voltages up to 35 kv inclusive are protected by type ПК (PK) quartz-sand-filled fuses (Fig. 241*a*). As can be seen from Fig. 241*a* the fuse comprises base *4* on which post insulators *3* are secured. The insulators carry contact clips *2* into which the porcelain fuse-link

the moving knife of the arc-extinguishing system. The stationary arcing contact is located in the lower part of the chute.

When the switch is opened, the working contacts separate first. After this the stationary and moving arcing contacts between which the arc is drawn separate. Acted upon by the high temperature of arc, the walls of the organic-material inserts generate gases (mainly hydrogen), which create a longitudinal blast serving to extinguish the arc. Lever-arm, manually operated ПРА-12 (PRA-12) and ПР-16 (PR-16) operating mechanisms are used to close and open these switches.

The supplementary part of the ВНП-16 (VNP-16) load-interrupter switch is a three-phase

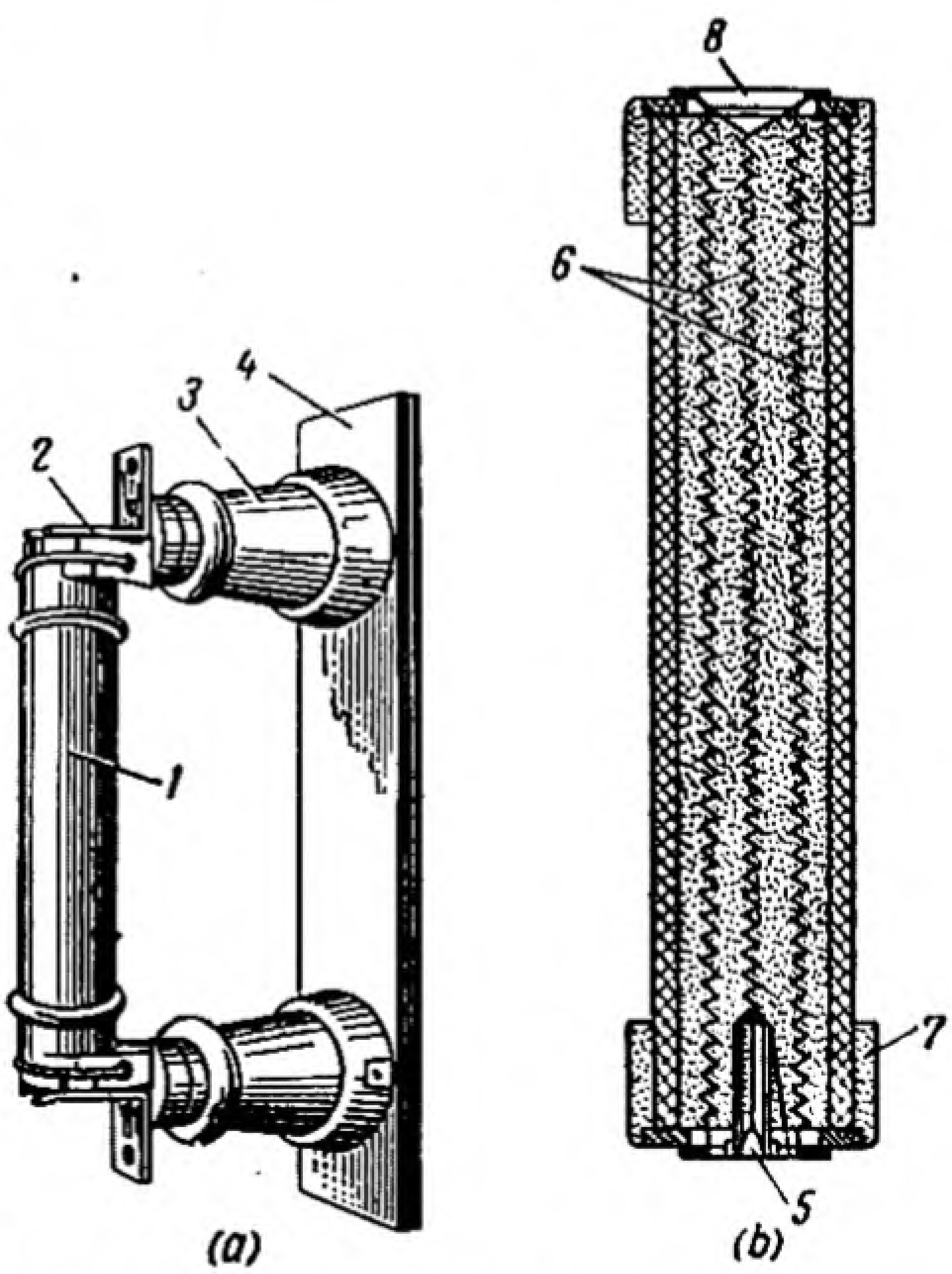


Fig. 241. ПК (PK) high-voltage fuse: *a*—general view, *b*—section through fuse-link case.

case *1* is inserted. The porcelain-tube case (Fig. 241*b*) is fitted at its ends with ferrules *7* provided with covers *8*. Fuse links *6* are arranged inside the case and the latter is filled with quartz sand to facilitate extinguishing the arc created when the fuse links blow out. The case also contains an indicating insert, one end of which holds indicator armature *5* inside the case.

When the fuse blows, the armature drops and permits the blown fuse to be very quickly detected. To protect voltage transformers (see further below) type ПКТ (PKT) high-voltage fuses are used. They differ in design from ПК (PK) fuses in that they are not fitted with an indicating aid. The indicating instruments to which they are connected show which fuse has blown out.

Power Transformers

In the high-voltage supply circuits of industrial undertakings power transformers serve to transform the voltage by stepping it down to the voltage ratings of the power consumer equipment.

Widely used in central and shop transformer substations are naturally cooled, oil-immersed, two-winding, three-phase transformers (Fig. 242).

Such a transformer has two main parts:

1) the removable core and windings assembly consisting of core *12* and windings *10* and *11*;

2) the outer part made up of tank *1*, its cover *2*, oil conservator *8* and the auxiliary components.

The core (or magnetic circuit) is assembled with three limbs (or legs), over which the wind-

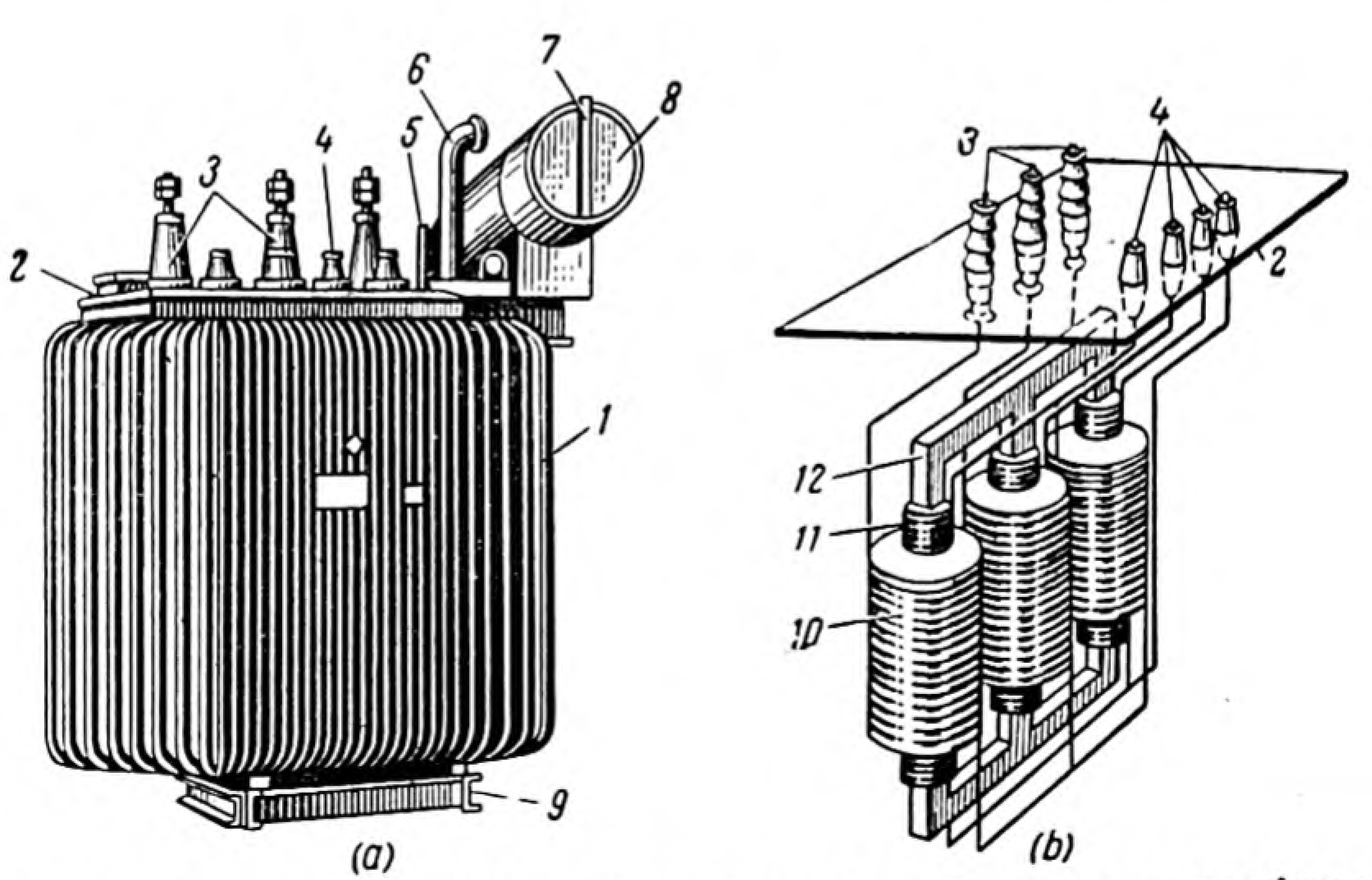


Fig. 242. Natural air-cooled, oil-immersed, three-phase power transformer: *a*—external view, *b*—core and windings assembly removed from transformer.

ings are fitted, and a top and a bottom yoke.

The two windings are arranged concentrically to each other, low-voltage windings *11* being fitted directly on each limb, with high-voltage windings *10* placed concentrically over them. Both windings are separated from each other by a layer of electrical pressboard. Leads from the ends of the high- and low-voltage windings connect them to the corresponding sets of terminal bushings *3* and *4* mounted in the cover of the transformer.

In addition to the main leads, several other leads are brought out from the high-voltage windings for connection to a tap changer under the transformer cover. To operate the tap changer, handle *5* is provided on the transformer cover.

The transformer tank holds the immersing oil and its heat-radiating surfaces serve to cool the oil in which the core and windings are protected from the action of the surrounding atmosphere.

Transformers in ratings up to 50 kva have smooth-wall tanks, but transformers with greater power ratings, up to 1,800 kva, have tanks fitted with tube-radiator cooling surfaces. Such tubes greatly increase the surface area through which the heat in the oil is transferred to the surrounding atmosphere.

Under changes in temperature, due to which the oil undergoes change in volume, the level of the oil in conservator *8* will also be in a state of change, but, since the conservator maintains the level at some height above the level of the transformer tank top, the tank always remains full of oil.

The oil conservator is furnished with oil gauge *7* to watch the oil level. Transformers rated for 750 kva and higher are supplied with pressure relief pipe *6* jointed to the transformer cover.

Relief pipe *6* serves to vent gases and oil when short circuits lead to excessive pressure within the transformer. The discharge opening of the pipe is sealed with a glass disk which is ruptured when the pressure rises during an emergency.

The transformer tank is mounted on a steel underframe furnished with steel rollers *9* on which the transformer can be rolled into a transformer cell or bay.

The tap changer (Fig. 243) permits the ratio of transfor-

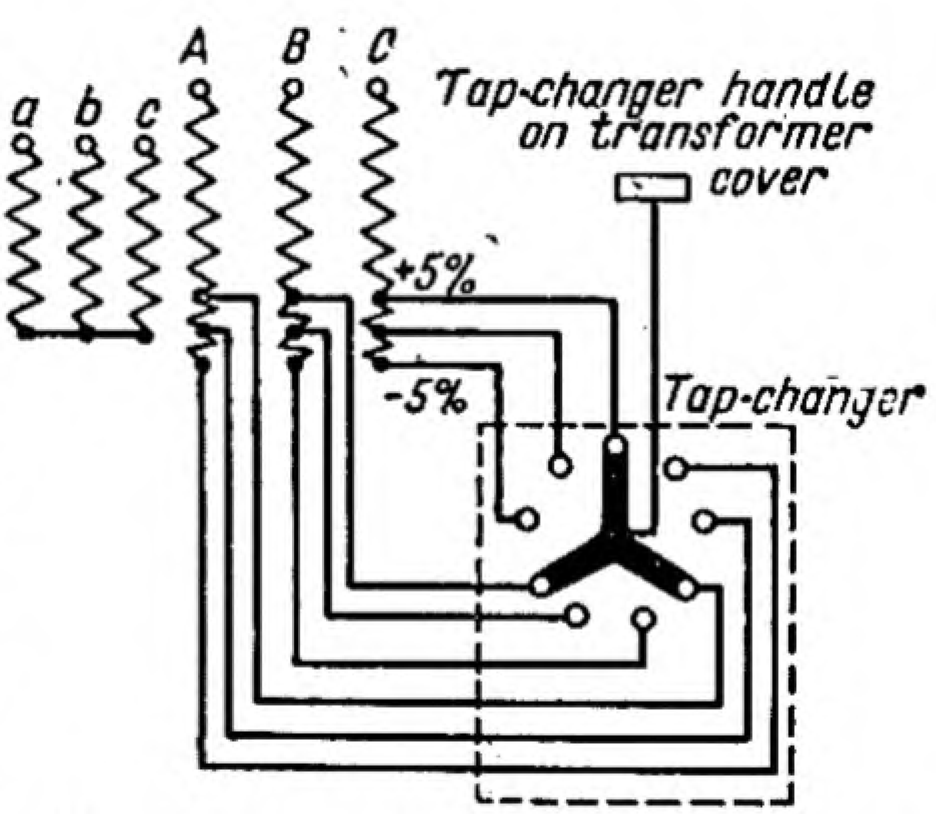


Fig. 243. Tap changer used to change number of turns for adjusting transformer voltage:

a, *b*, *c*—low-voltage windings, *A*, *B*, *C*—high-voltage windings.

mation of the transformer to be changed within a range of ± 5 per cent and thus adjust the voltage across the secondary winding to its required rated value.

Transformers have the following main rating values: rated power (kva), rated primary voltage, rated secondary voltage, and a specified standard vector group of connection of the windings, i.e., the way in which the high-voltage and low-voltage windings are respectively interconnected to ensure one or another angle of phase shift of the winding line voltages relative to one another.

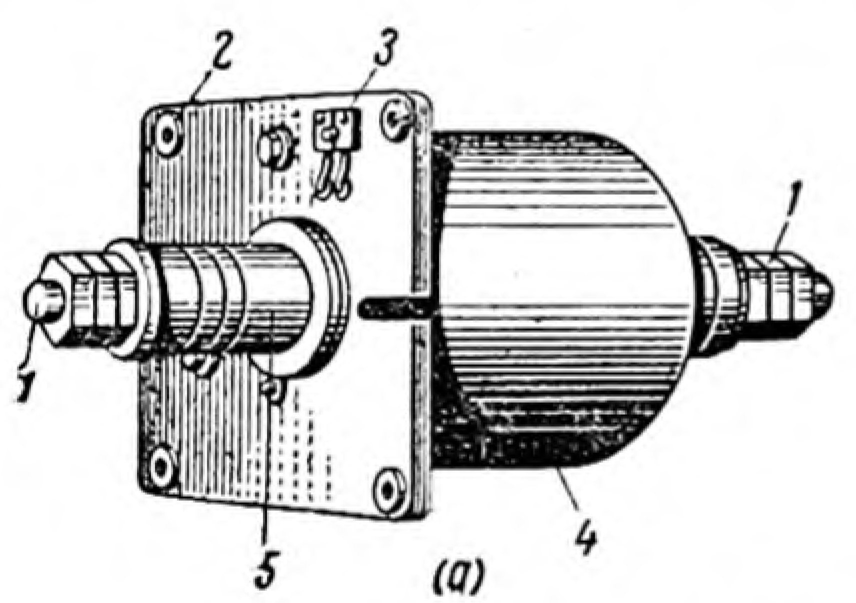
Current Transformers

Current transformers are instrument transformers interposed in a-c power circuits to feed the current coils of protective, and indicating and metering instruments (ammeters, wattmeters, watthour meters, relays), to broaden the limits of measurement and to control and maintain a watch over the currents flowing in the circuits and over the power loads.

In high-voltage installations current transformers, in addition to the above, also isolate the indicating and metering instruments from high voltage.

The basic element of a current transformer is its core on which are wound a primary and one or two secondary windings.

The primary is directly interposed in the circuit in which the power current is to be measured. To the secondary winding (or windings) the indicating and



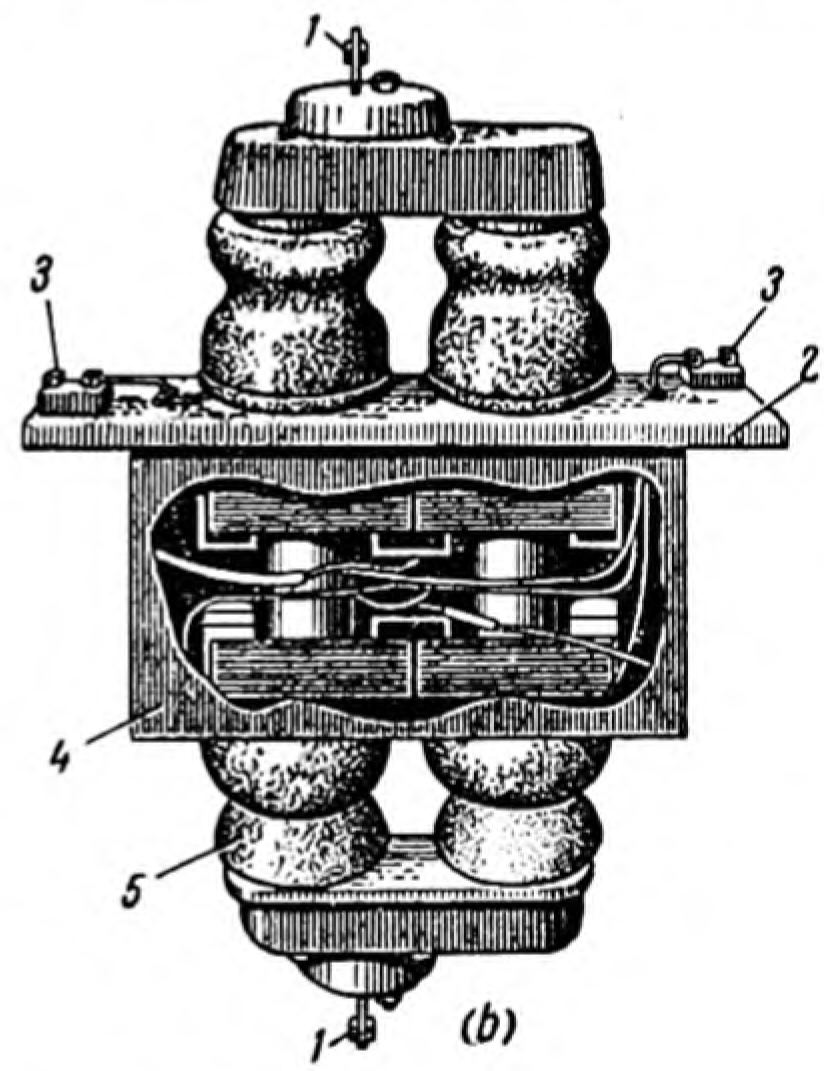


Fig. 244. High-voltage current transformers:

a—type ТПОФ (TPOF) single-turn primary current transformer, *b*—type ТПФ (TPF) multi-turn primary current transformer; *1*—primary winding terminal, *2*—mounting flange, *3*—secondary winding terminal, *4*—case, *5*—insulators.

metering instruments and relays are connected.

When the rated current of a current transformer flows through its primary winding, a current of 5 amperes will appear in its secondary winding.

The ratio of the primary current to the secondary current is called the turns ratio or ratio of transformation of the current transformer.

Depending upon how many times the actual primary current is greater or less than the current rating, the greater or less is the secondary current in relation to 5 amperes.

According to the number of turns used in the primary winding, current transformers are classed as single-turn (for large primary currents) and multi-turn (for relatively small primary currents).

Indoor switchgear installations employ mainly through-class current transformers such as type ТПОФ (TPOF)—meaning current transformer, through-class, single-turn primary, with porcelain insulation (Fig. 244*a*) and type ТПФ (TPF)—meaning current transformer, through-class, multi-turn primary, with porcelain insulation (Fig. 244*b*).

Such current transformers are mounted within wall and floor structure openings, and simultaneously serve as bushings.

The main ratings by which current transformers are characterised are the rated voltage of the insulation, the rated currents of the primary and secondary windings and the accuracy class.

The accuracy class indicates the limit of the current transformer errors in per cent of the rated turns ratio of the given current transformer. Current transformers are available in the accuracy classes 0.5; 1; 3 and 10.

Voltage Transformers

Voltage transformers are instrument transformers used for voltages from 380 volts upward to feed the voltage coils and windings of indicating and metering instruments and relays (see Chapter VIII dealing with relays). Such transformers make it possible to expand the limits of measurement of ordinary low-voltage instruments and isolate them from high voltage.

Fig. 245 shows a three-phase voltage transformer of the oil-immersed type. Within tank *1*

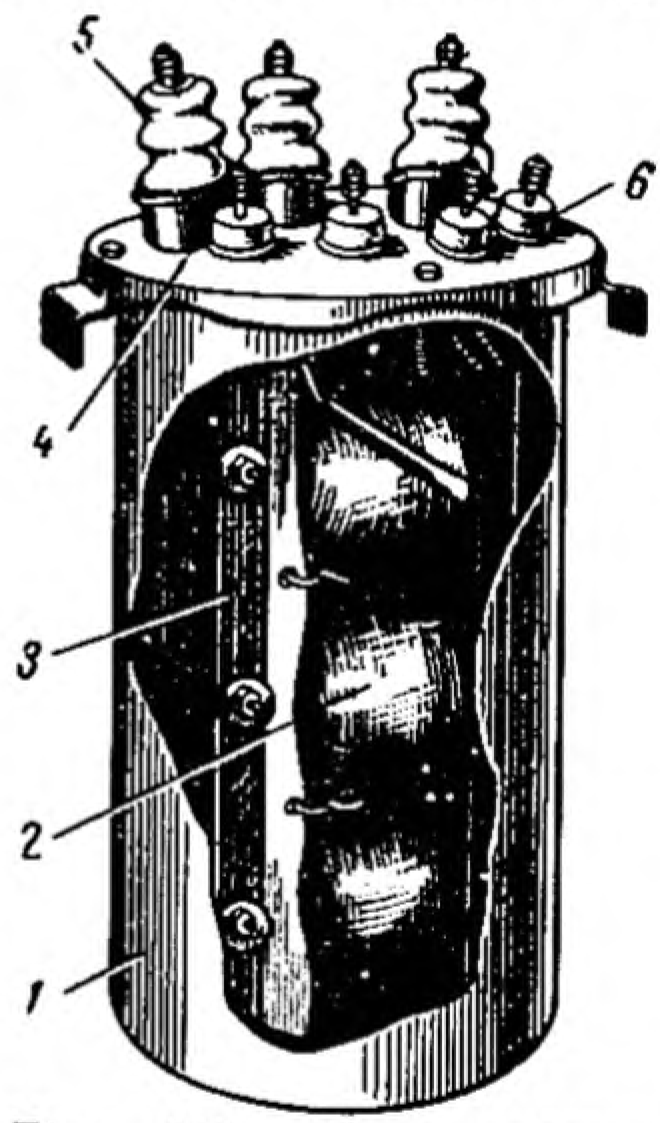


Fig. 245. Type НТМК-6 (NTMK-6) three-phase, oil-immersed voltage transformer.

filled with transformer oil is arranged core *3* with limbs which carry three-phase windings *2* for the high (primary) and low (secondary) voltages.

The core assembly is attached to transformer cover *4* in which

are mounted high-voltage primary terminal bushings *5* and low-voltage secondary terminal bushings *6*.

The primary windings of voltage transformers serve for connection to the main bus-bars of switchgear installations. To the secondary windings various indicating-metering instruments and relays are connected.

When the rated high voltage is applied to the primary, the voltage across the secondary winding equals 100 v. The ratio of the rated primary voltage to the rated secondary voltage is called the *turns* or *transformation ratio*. Any increase or decrease in the voltage applied to the primary winding causes a proportional change in voltage across the secondary winding.

Voltage transformers are available in single-phase and three-phase designs.

The main ratings by which voltage transformers are characterised are the rated primary and secondary voltages, accuracy class, number of phases, system of cooling.

Within indoor 6- and 10-kv switchgear installations use is made of the following types of voltage transformers:

a) НОМ-6, НОМ-10 (NOM-6, NOM-10)—single-phase, oil-immersed transformers rated for 6 or 10 kv;

b) НТМИ-10, НТМК-6, НТМК-10 (NTMI-10, NTMK-6, NTMK-10)—three-phase, oil-immersed transformers rated for 6 or 10 kv, the letters И (I) or К (K) indicating the presence of special windings.

4. Indoor Substations 6 and 10 kv

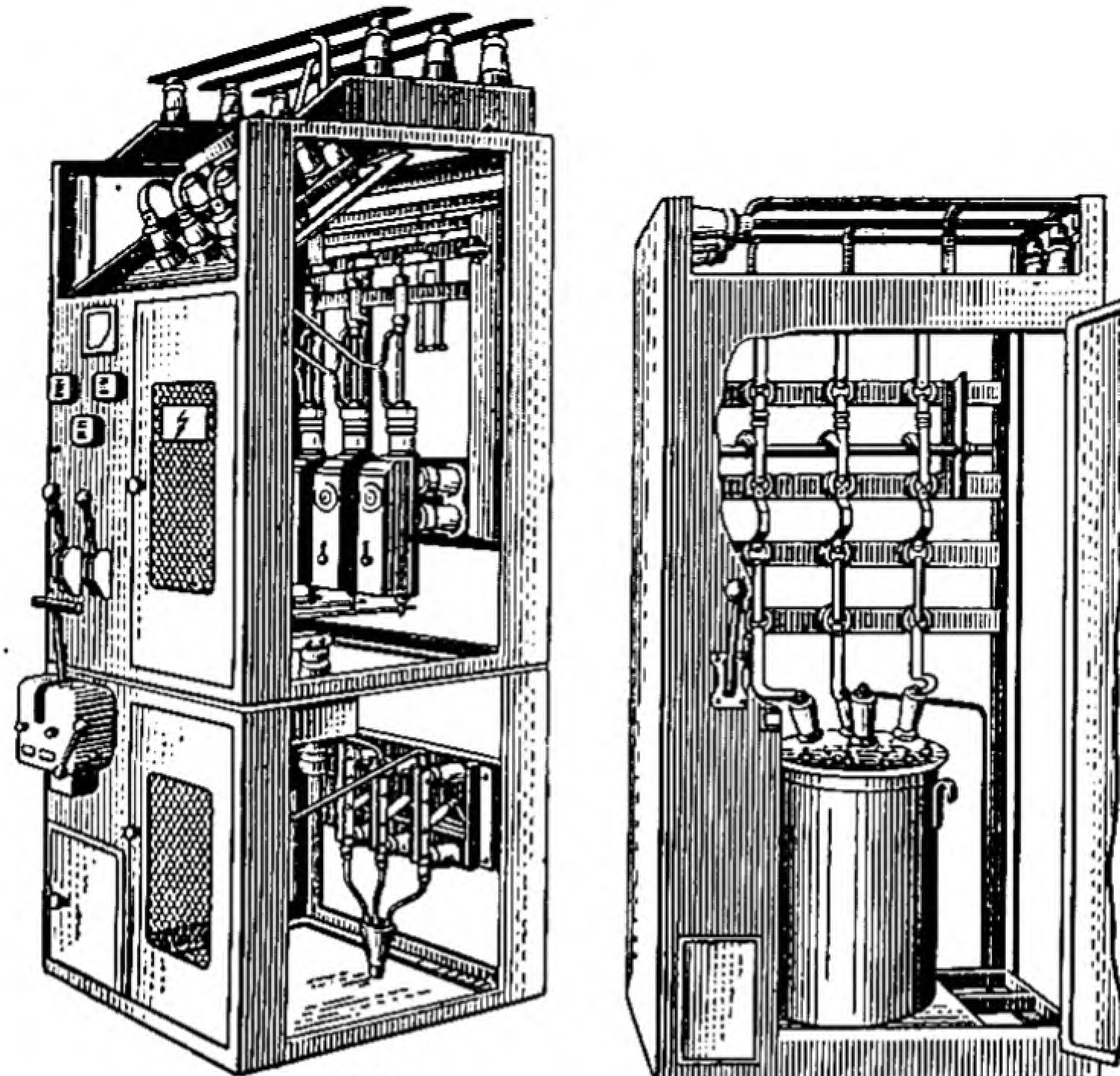
Indoor distribution and transformer substations, as well as high-voltage switchboards, consist of a series of open and enclosed chambers or compartments in which the main equipment of the given installation is arranged. The chamber space within which the equipment of any one main bus-bar connection is mounted, as a whole, is termed a *cell*, *cubicle* or *compartment* (supply-entrance cell, power-transformer cell, voltage-transformer cell, etc.).

In addition to the various cells, cubicles or compartments, substations containing a large number of such units are laid out so that they have aisles for performing control operations and for servicing-control aisles and servicing aisles.

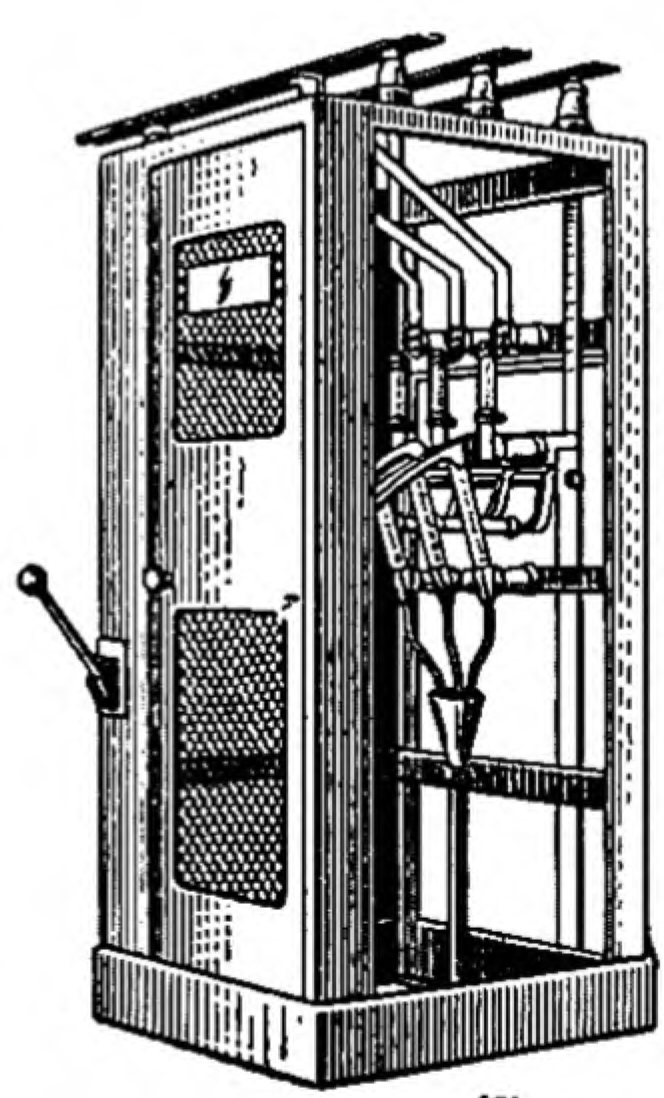
As to construction, indoor distributing and transformer substations and high-voltage switchboards can be subdivided into three kinds:

1. Substations of the integrally built type in which the equipment is installed on site. In such substations the cell structures are constructed of concrete or brick.

2. Substations of the composite, built-up type in which the assemblies and parts are factory or workshop prefabricated, but are assembled on site within a substation switchgear room. The compartments of such substations take the form of metal cabinets or enclosures each of which contains the equipment



(a) (b)



(c)

Fig. 246. КСО (KSO) single-side serviced, prefabricated switchgear compartments for composite on-site assembly:

a—compartment containing a ВМГ-133 (VMG-133) oil-minimum circuit breaker; b—compartment containing a НТМИ (NTMI) voltage transformer, c—compartment containing a ВНП-16 (VNP-16) load-interrupter switch.

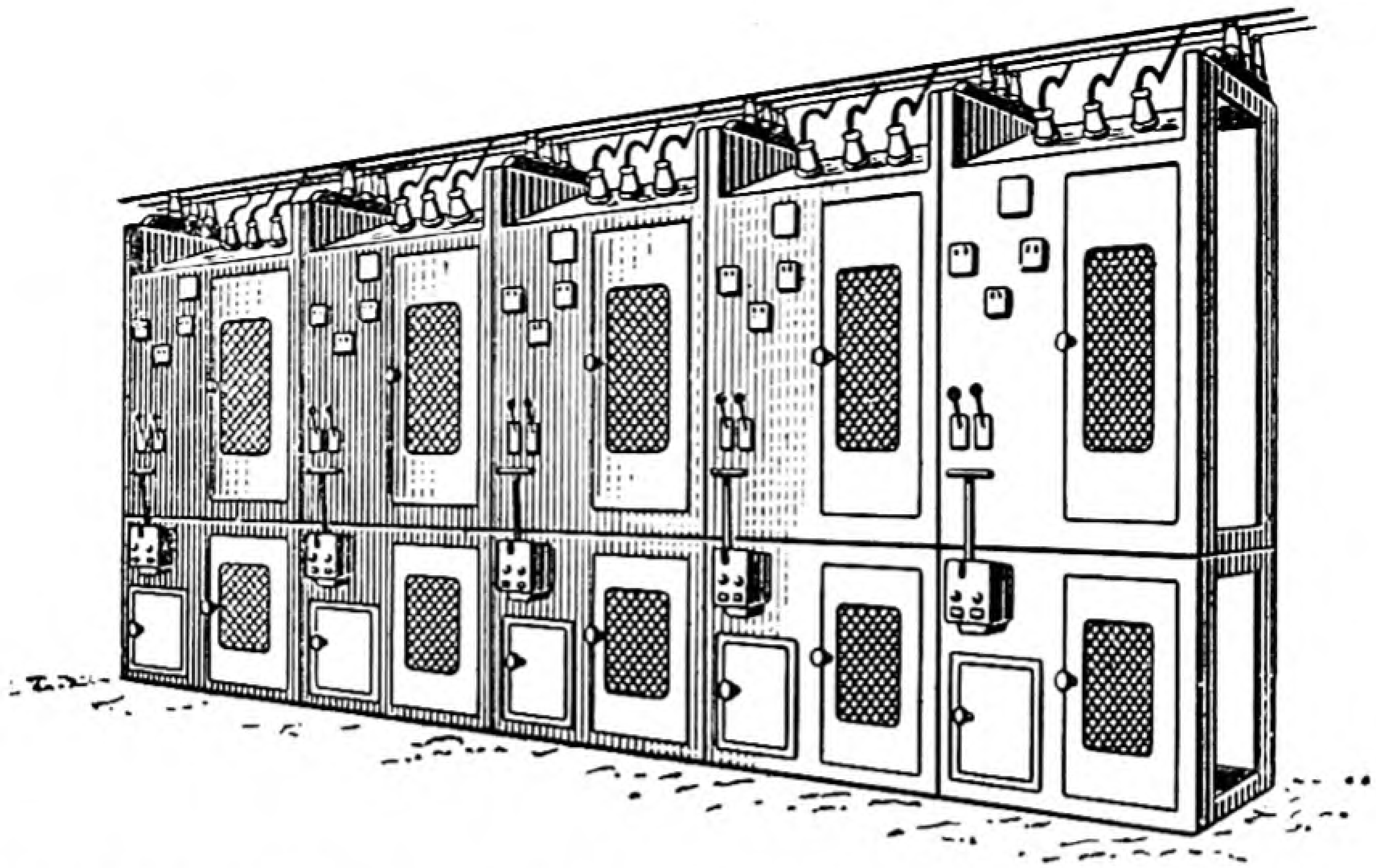


Fig. 247. Switchgear installation assembled of КСО(KSO) compartments.

of one main-connection cell. Such cabinets or enclosures are called КСО (KSO) compartments (meaning compartment, composite, single-side serviced). Within them may be mounted an oil-minimum circuit breaker (Fig. 246*a*), a load-interrupter switch (Fig. 246*c*), one or more voltage transformers (Fig. 246*b*), etc. The general appearance of a switchgear installation assembled of such compartments is given in Fig. 247.

3. Unit-type, factory fabricated substations and metalclad switchboards which are built in electrical engineering works and are shipped to the site of installation fully preassembled. After installation such substations and switchboards practically only require connection to the incoming and outgoing power circuits.

КРУ (KRU) cubicles for unit-type switchboards or substations take the form of fully enclosed metalclad cabinets.

Wide use is made of KRU metalclad cubicles designed with withdrawable trucks and divided into several compartments (Figs 248 and 249*a*): control compartment *1*, indicating and metering instrument and protective device compartment *2*,

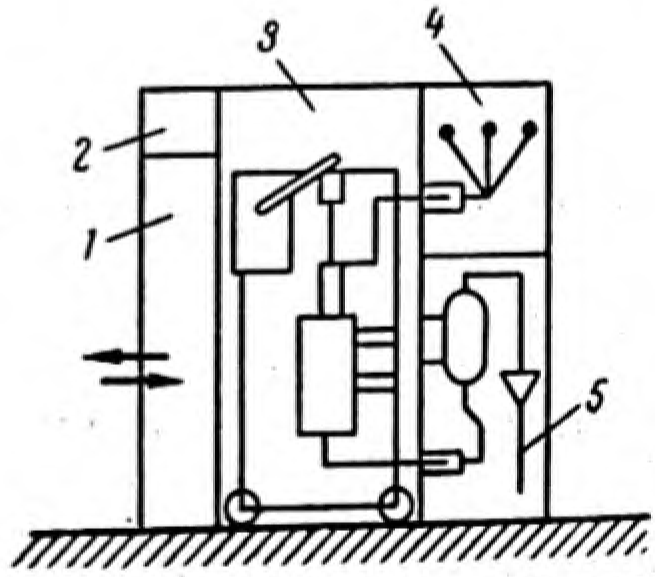
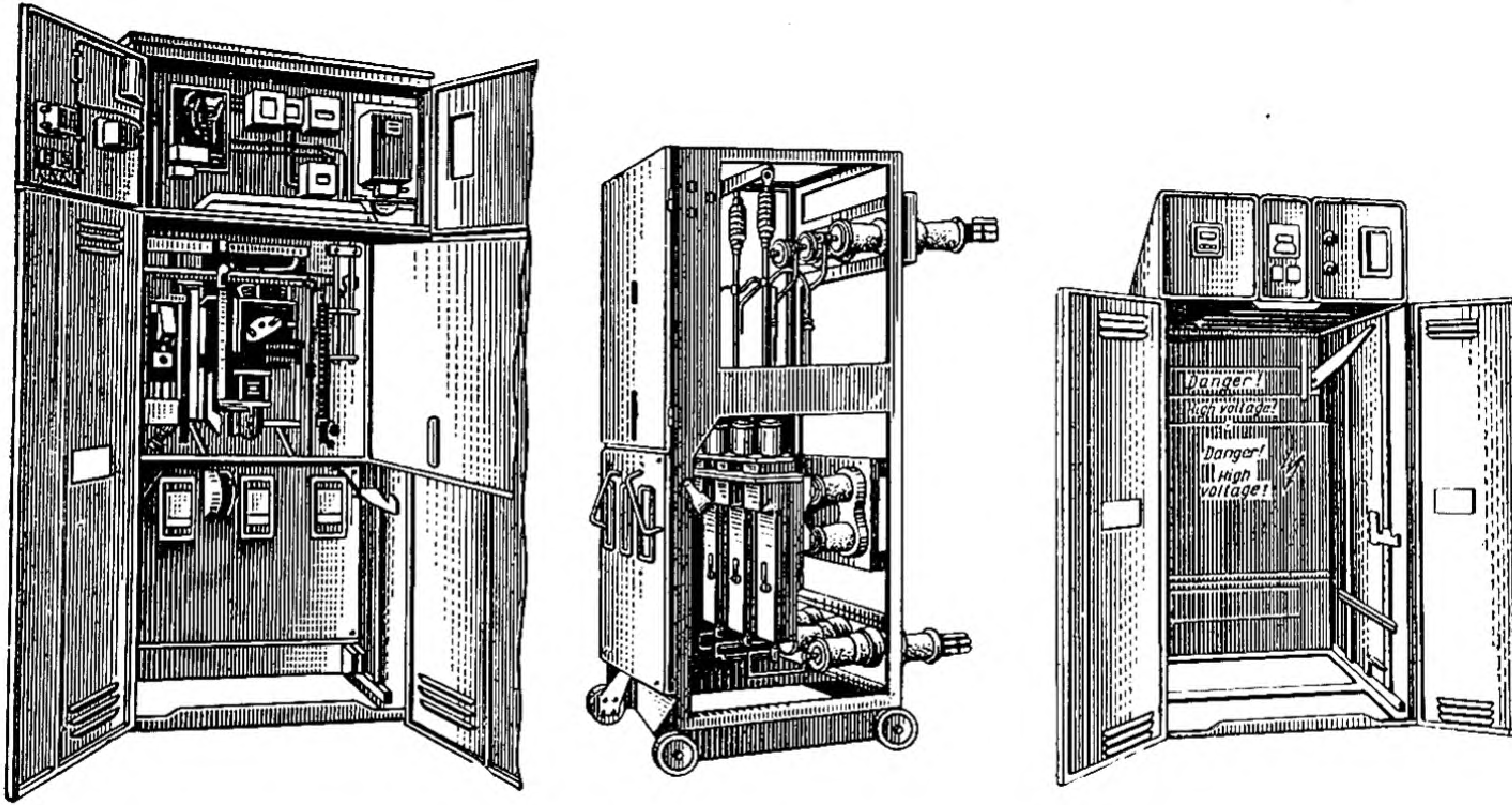


Fig. 248. Diagram of КРУ (KRU) cubicle.



(a) (b) (c)

Fig. 249. КРУ (KRU) cubicle with ВМГ-133 (VMG-133) circuit breaker:
a—internal view of cubicle, b—truck-mounted circuit breaker, c—cubicle without truck.

circuit breaker and operating mechanism compartment *3*, main-bus-bars compartment *4*, and compartment *5* for the current transformers and cable sealing boxes.

Partitioning of the cubicle space into compartments provides safe access to the apparatus. The circuit breaker and its operating mechanism are mounted on the truck, which can be withdrawn from the cubicle.

In withdrawal-truck unit-type cubicles the disconnecting or isolating device is of the plug-in (cluster contact) type (Fig. 249*b*).

When a truck is rolled out from the cubicle the holes which the disconnecting devices enter for making contact are automatically closed (Fig. 249*c*) by metal shutters serving to isolate the live parts from possible casual contact. When the truck is rolled back into the cubicle, the shutters open automatically.

To prevent any possible opening or closing of the disconnecting devices when the circuit breaker is closed, these cubicles are designed with interlocks which prevent the truck from being rolled in or withdrawn when the circuit breaker is closed.

The trucks of KRU unit-type cubicles may occupy three positions: 1) working position—truck fully in and up against stops, disconnecting devices fully in contact; 2) testing position—truck withdrawn far enough to have disconnecting devices fully separated, but still within the cubicle, and also with all the control, signal, protective relay and metering circuits still unbroken; 3) repair position—truck fully withdrawn from the cubicle.

A general view of a unit-type, metalclad switchboard assembled of several metalclad cubicles can be seen in Fig. 250.

Fig. 250. General view of a unit-type metal-clad switchboard.

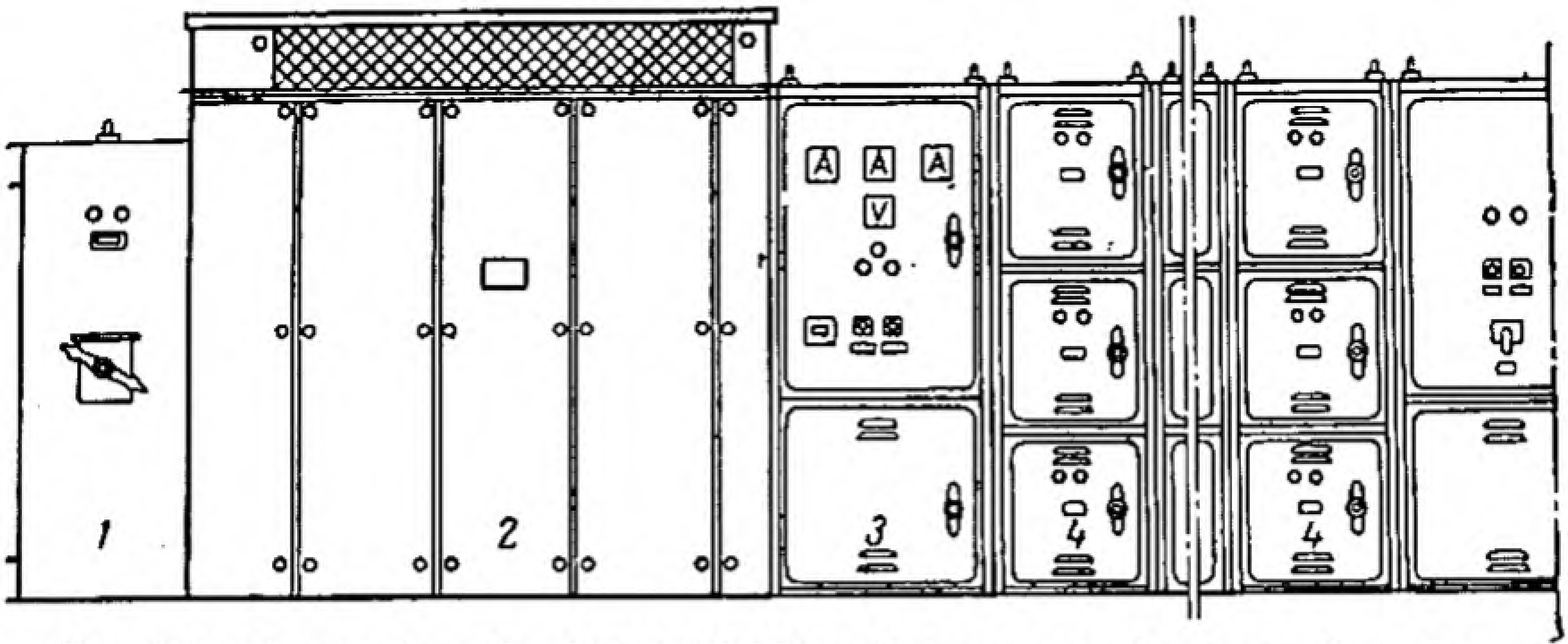


Fig. 251. Front view of a КТП (KTP) unit-type transformer substation.

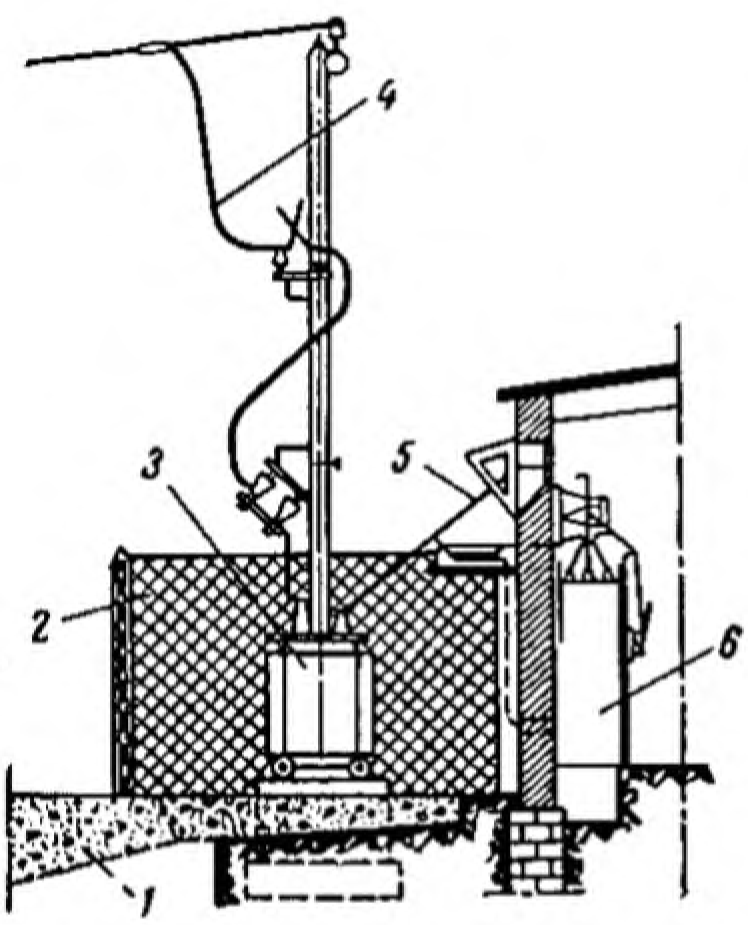


Fig. 252. Sectional view of a transformer substation partially built into an industrial shop:

1—water drain gutter, 2—guard fence, 3—power transformer, 4—overhead high-voltage service lead, 5—low-voltage service lead, 6—low-voltage switchboard.

The appearance of a unit-type transformer substation — КТП (KTP)—is shown in Fig. 251.

In the unit-type КТП (KTP) transformer substation the metal-clad cubicles (Fig. 251) house the primary and secondary voltage equipment and also the power transformer.

The power intake apparatus is arranged in cubicle *1*; cell *2* houses the TC self-cooled, dry-type power transformer, which in such substations can have a rating from 180 to 560 kva; cubicle *3* contains an air circuit breaker for disconnecting the transformer from the low-voltage switchgear; and cubicles *4* contain the low-voltage, outgoing-feeder air circuit breakers.

Such a unit substation can be installed directly within a shop (provided its atmosphere is dry enough and the ventilation is adequate). It thus becomes what was earlier termed an "in-shop" substation.

Transformer substations may be partially built into the shops of industrial undertakings (as illustrated in Fig. 252). It is very frequent practice to build separately standing substations on the territory of industrial works (Fig. 253).

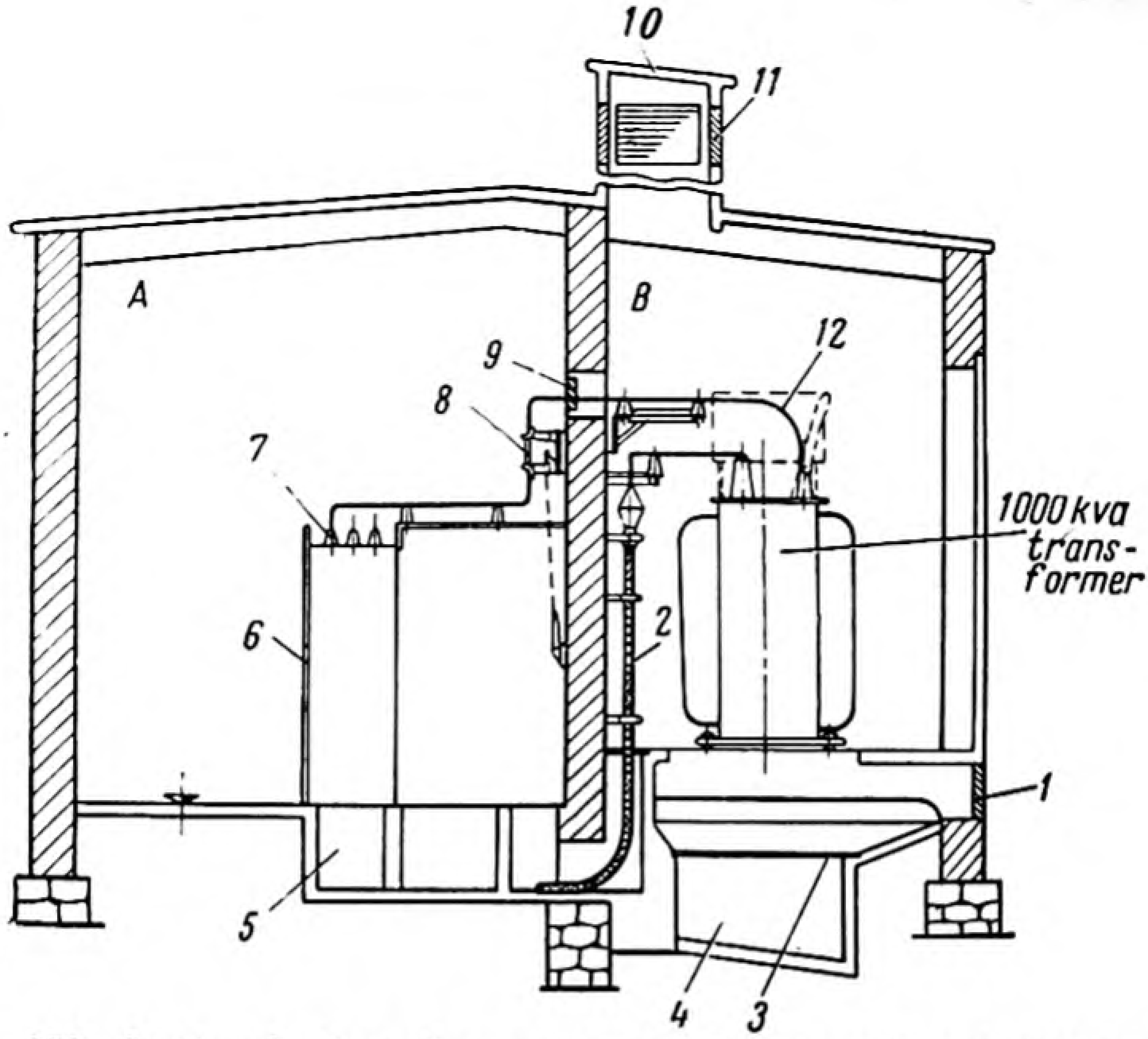


Fig. 253. Sectional view of a power transformer cell and distribution switchboard in a separately standing transformer substation:

A—distribution switchboard room, *B*—power transformer cell; *1*—cold-air ventilation opening and grating, *2*—cable for supplying transformer, *3*—fire-prevention grating with layer of gravel, *4*—oil sump, *5*—trenches provided under switchboard for laying of cables, *6*—low-voltage distribution switchboard, *7*—distribution switchboard main bus-bars, *8*—isolator, *9*—insulating panel for passage of buses, *10*—hot-air ventilating shaft, *11*—air-discharge louvres, *12*—bus-bar leads from low-voltage terminal bushings.

Chapter VIII

MAIN FEATURES OF PROTECTIVE RELAYING, SIGNAL CIRCUIT AND INTERLOCKING ARRANGEMENTS

1. General

Whenever electrical installations operate, abnormal conditions of operation may arise in them. In the majority of cases such conditions lead to short circuits which develop as a result of a breakdown or flashover of the insulation, breakage of a conductor, or wrong performance of a switching operation by a duty attendant.

Overloads, when allowed to persist too long, lead to excessive temperature rises in current-carrying parts and to destruction (breakdown) of the insulation in cables, machine windings and apparatus coils. To prevent an emergency which occurs in one part of a circuit from spreading to the healthy sections of the circuit, the faulted part must be automatically switched out of circuit.

Automatic switch-out of circuits on occurrence of emergencies in substations and switchgear installations operated at

voltages over 1,000 volts is initiated with the aid of special devices—the protective relays.

For disturbances other than the above, for example, when an overload appears, there is no need for immediate disconnection of the equipment, but an alarm signal should be instantly sounded or lighted to warn of appearance of such a condition. Furthermore, to operate safely high-voltage power circuits, in many cases it is necessary to know what position the contacts of certain apparatus are in at any given instant of time (whether open or closed). This function is performed by a system of signal circuits and devices.

Wrong sequence of any operation by an attendant is prevented by a special system of interlocking circuits and arrangements.

The above-mentioned systems of protective relay, alarm and signal, and interlock circuits and their equipment make up what is termed the ancillary or secondary circuits as compared to the primary or power circuits and equipment discussed earlier.

Ancillary or secondary circuits receive their power supply from what are called *operative-power sources* in order to perform their various control functions.

The circuits through which operative currents flow are called *operative circuits.*

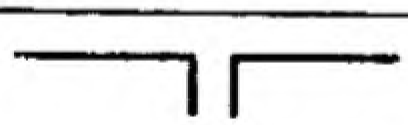
Installations of low power capacity mainly use a-c operative power obtained from instrument current transformers and voltage transformers.

In large substations with remote control and complicated protective-relay and automatic-control systems, d-c operative power is used. This power is obtained from charged storage batteries (ranging from small batteries with voltages of 12, 24 and 48 volts up to powerful batteries with voltages of 110 and 220 volts). These storage batteries are always maintained in a charged condition by battery-charging units in the form of motor-generator sets or rectifiers.

In order to show the various instruments, relays, apparatus and other elements incorporated in the circuits secondary-wiring circuit diagrams represent them by graphic symbols such as in Table 29 (taken from the U.S.S.R. Standard for electrical circuit drawing symbols).

Table 29

Graphic Symbols for Representing Various Circuit Elements on Substation Secondary-Wiring Circuit Diagrams

Symbol	Name of element or device
	Normally-open contact (n. o.)
	Normally-closed contact (n. c.)

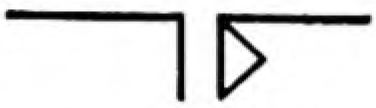
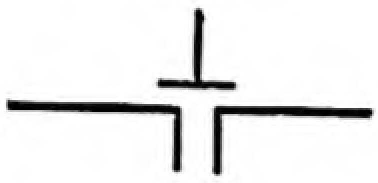
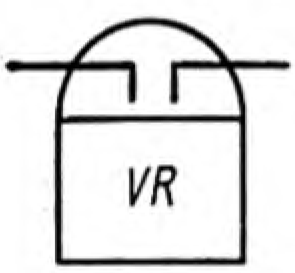
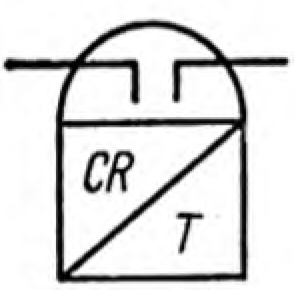
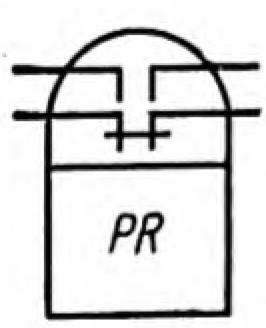
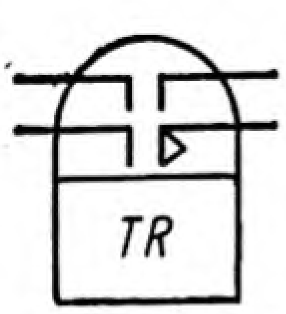
Symbol	Name of element or device
	Normally-open contact with time delay on opening
	Normally-open contact, latched type for hand resetting
	Instantaneous current relay with one normally-open contact
	Instantaneous voltage relay with one normally-open contact
	Current relay with inverse time characteristic and with one normally-open contact
	Power relay with one normally-open and one normally-closed contact
	Time-lag (or time delay) relay with one normally-open instantaneous contact and one normally-open contact with time delay on opening

Table 29 continued

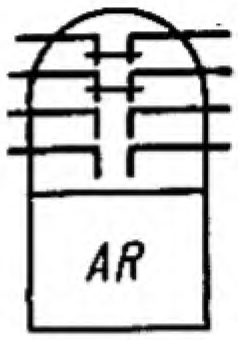
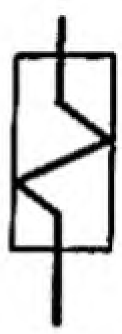
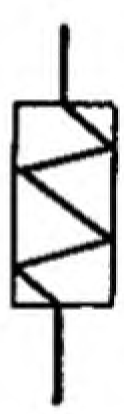
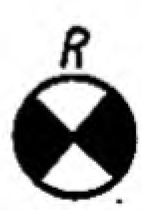
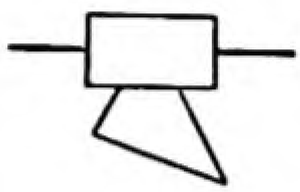
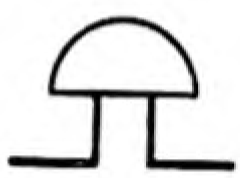
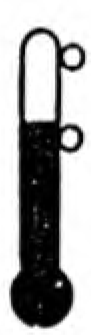
Symbol	Name of element or device
	Auxiliary relay with several contacts
	Signal relay with hand reset
	Trip coil TC (electromagnet with series winding)
	Electromagnet with shunt winding
	White signal lamp
	Red signal lamp
	Green signal lamp

Table 29 continued

Symbol	Name of element or device
	Alarm (emergency) signal lamp
	Electric siren, horn, howler
	Electric bell
	Two-pole change-over switch
	Mercury thermometer with electric contacts

Circuit diagrams for representing the electrical connections of secondary wiring systems may be divided into elementary (or basic) circuit diagrams, full circuit diagrams and wiring diagrams.

Elementary circuit diagrams (Fig. 254) serve only to show the principle of operation and the electrical relationships of the various instruments, relays and apparatus in the circuit relative to one another. Such diagrams are drawn for separate parts of a main connection and are used for full circuit diagrams and wiring diagrams.

Full circuit diagrams (Fig. 255) give completely all the connections of the secondary wiring system of some given

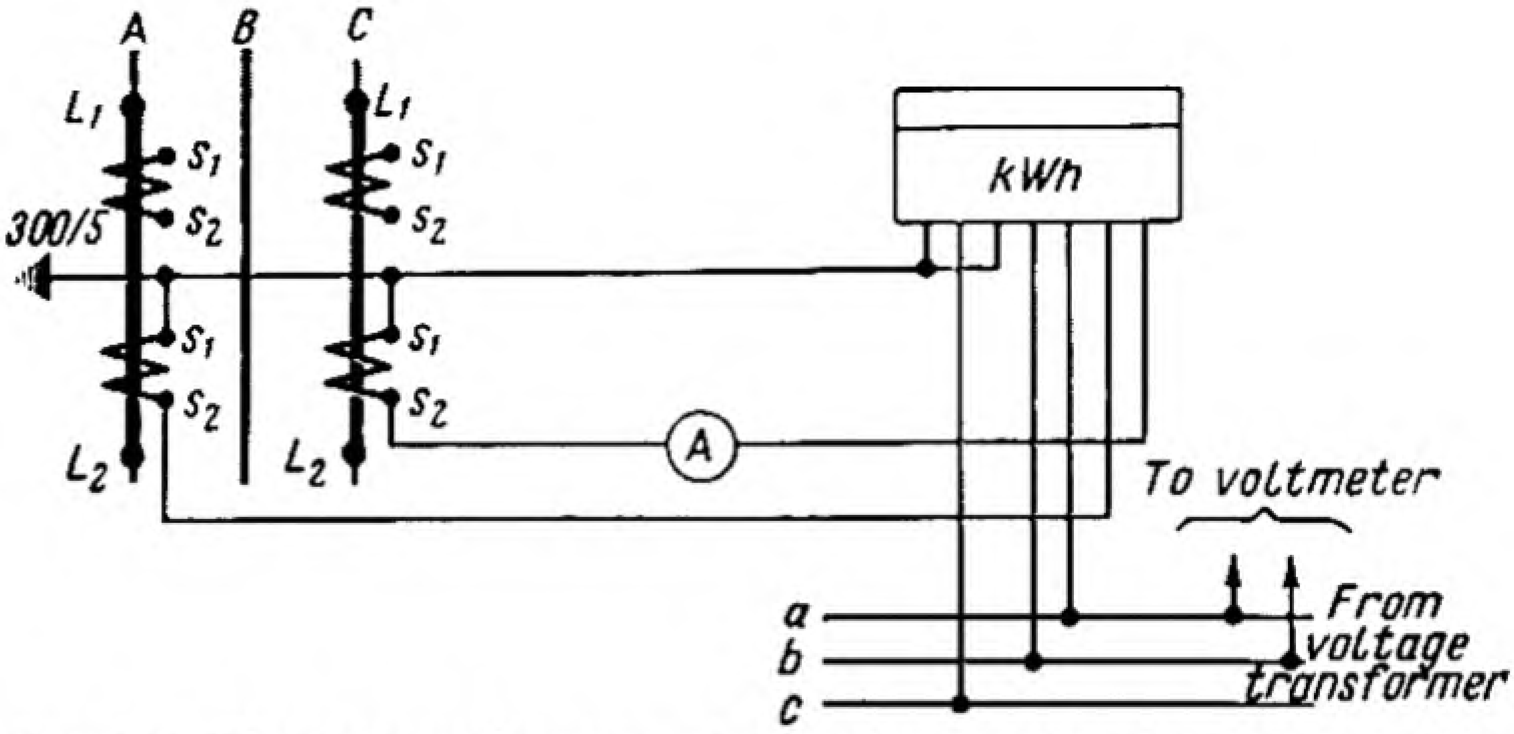


Fig. 254. Elementary diagram of secondary wiring for separate part of a main connection.

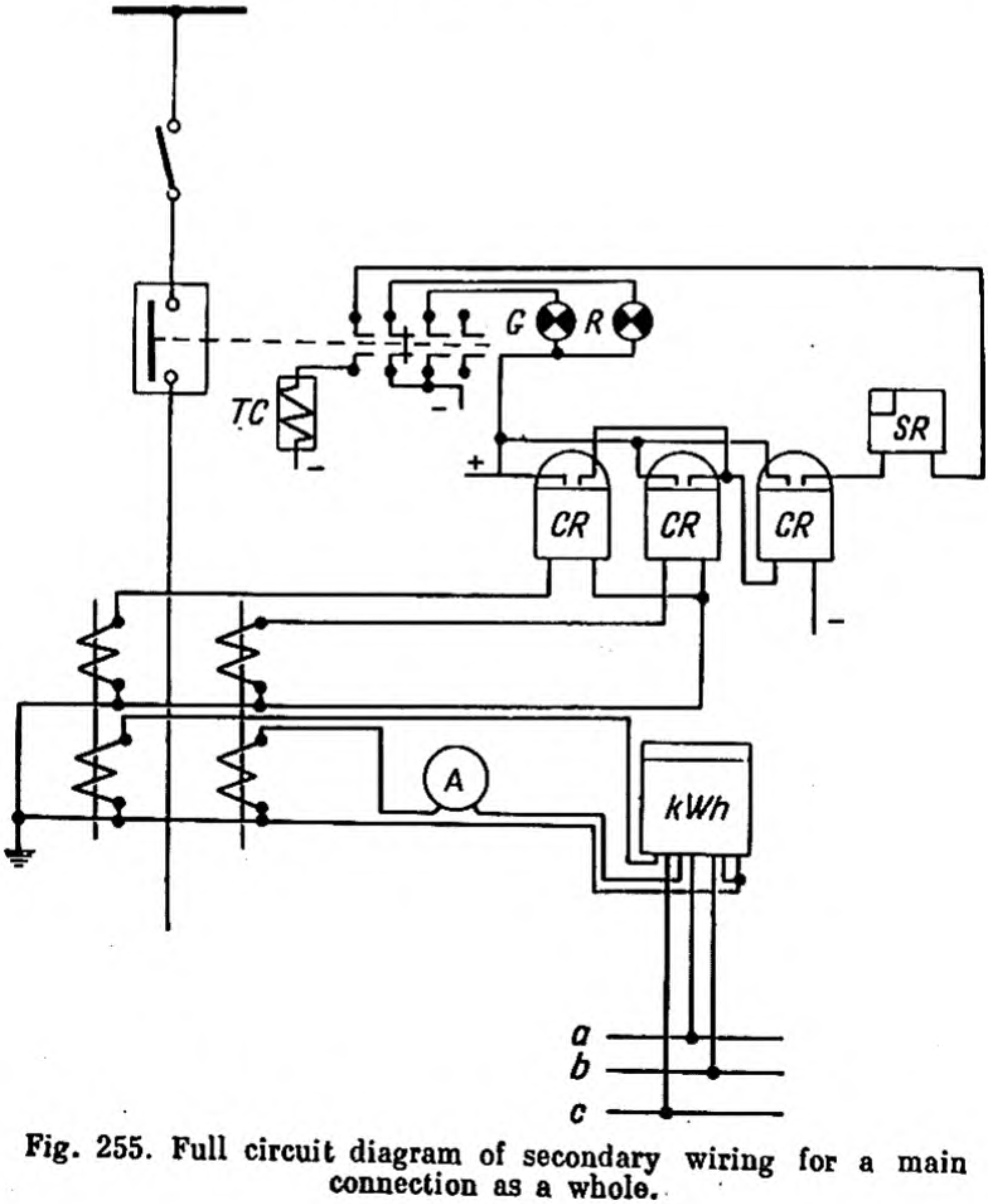


Fig. 255. Full circuit diagram of secondary wiring for a main connection as a whole.

main connection. These diagrams show how the protective relays, the automatic control and signalling devices, and the controls are used for operating and protecting the given main connection function, both under normal operating conditions and in the event of an emergency.

Wiring diagrams (Fig. 256) are drawn according to the full

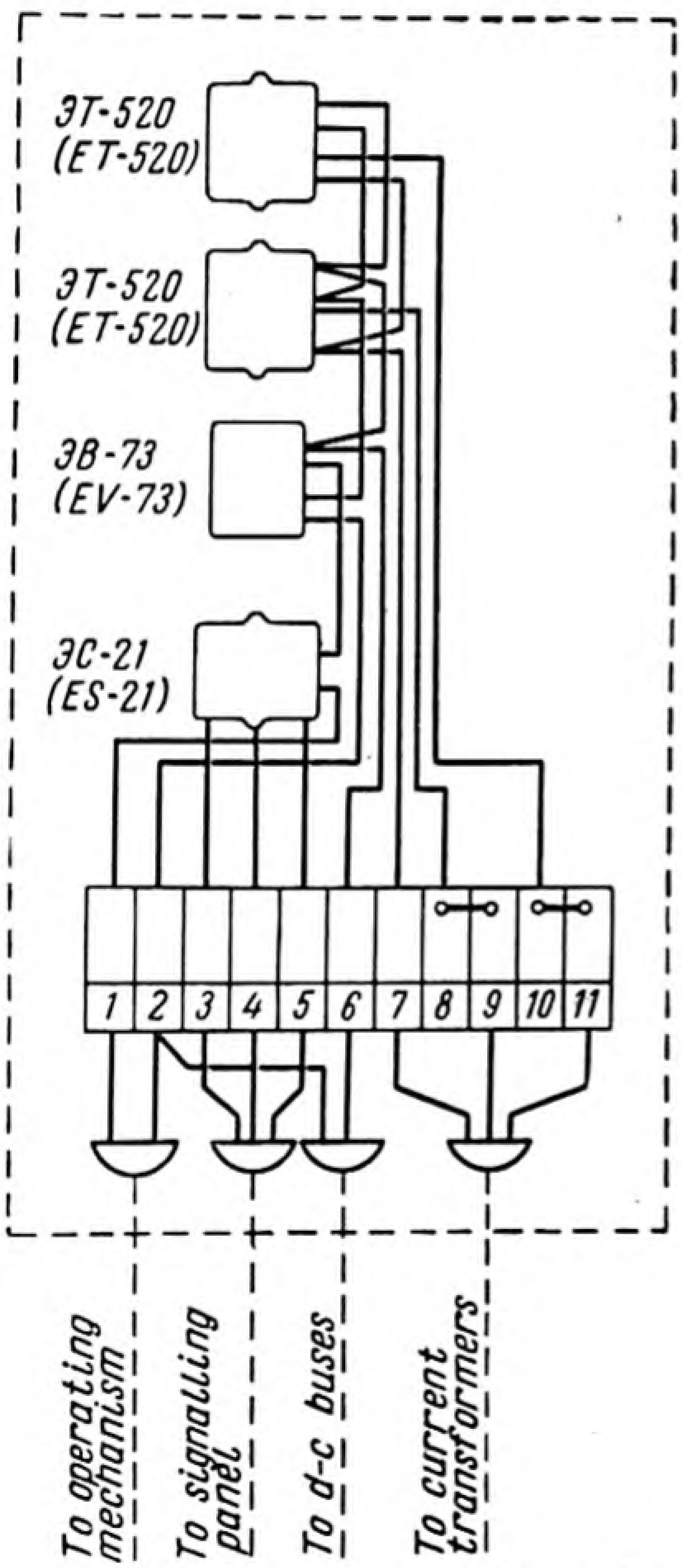


Fig. 256. Wiring diagram of secondary wiring on a relay panel:

Numbers *1* through *11* indicate the order of the separate terminals on the terminal block.

circuit diagram. They are working drawings and are used by the installer to put the wiring in and make the necessary connections. They also serve for trouble-shooting when the installation is in service.

Wiring diagrams are made to scale and show the outlines of the apparatus, devices, etc., which are to be wired on some given panel or at some particular place. Represented on these diagrams are all the hook-up wires, control cables, cable end seals and connections on terminal blocks.

2. Relay Protection Systems

Main Features

A relay protection is an arrangement of electrical devices used to provide definite automatic protective action and consisting of one or several relays connected according to a given electrical scheme.

Fig. 257 shows the schematic circuit diagram of a relay protection for a power-line main connection. In examining the way in which the circuit functions, note that any rise in the load current taken by line *1* (because of an overload or short circuit) will lead to a corresponding increase in the current flowing through the secondary winding of current transformer *2* and coil *3* of relay *4*. As a consequence, armature *5* is drawn into its coil, overcomes the resistance of spring *S*, causes

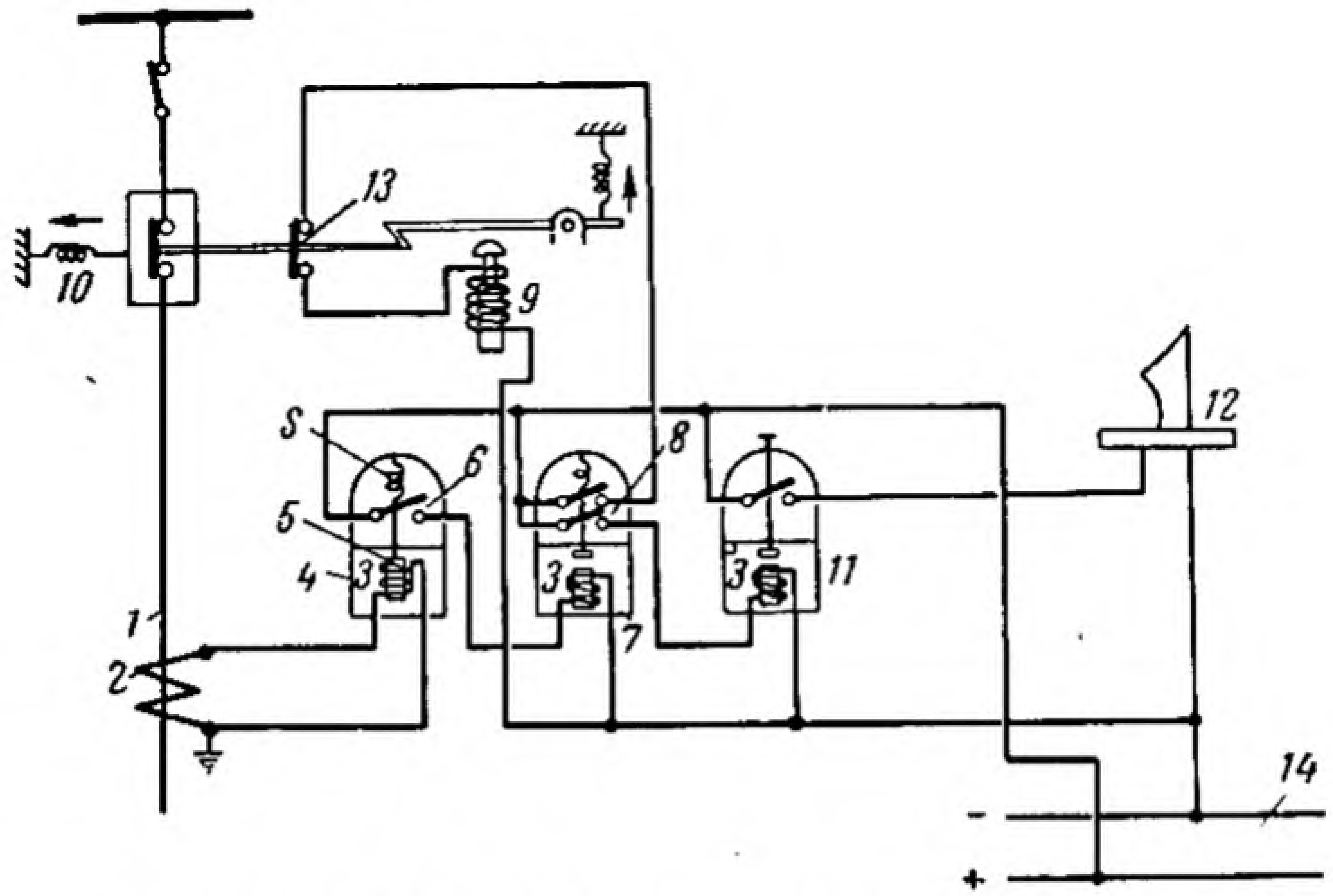


Fig. 257. Schematic circuit diagram showing mode of operation of a relay protection.

control contact *6* to close and thus completes pick-up of relay *4*.

As soon as relay *4* operates, normally-open contact *6* closes the supply circuit to energise the operating coil of relay *7* and make the latter close normally-open contacts *8*. This creates two control pulses: one to trip coil *9* in the operating mechanism controlling circuit breaker *10*, the other to energise the coil of relay *11*. The instant relay *11* picks up, its contact switches on alarm siren *12*. When circuit breaker *10* trips open, the circuit feeding trip coil *9* is broken by auxiliary switch contact *13*, and relays *4* and *7* reset in their initial positions. However, the contact of relay *11* still remains closed because it requires hand resetting (it has no reset spring). Siren *12* will consequently continue to operate until the duty attendant resets the contact of relay *11* in its initial (open) position.

All the operative circuits receive supply from operative-power buses *14*, in this case connected to a d-c source.

Fig. 257 shows that the main (protective) relay in the scheme is relay *4* because it initiates action of the protection circuit. The other relays (*7*, *11*) have only auxiliary functions.

Principal Protective Relays

Among the main (protective) relays used in protective relaying, the overcurrent relays, devices designed to respond to current increases in a protected circuit, find the greatest application.

Overcurrent relays are classed as indirect-acting (designed to act upon the circuit-breaker

operating mechanism trip coil by means of auxiliary relays and circuit arrangements) and as direct-acting (designed to act directly upon the circuit-breaker operating mechanism trip device).

The smallest current in an overcurrent relay at which it will reliably operate is called the *operating* or *pick-up current.*

The given value of the operating current for which the relay is adjusted and at which it must operate is called its *current setting*. Each overcurrent relay is designed for a certain range of current settings (for example, from 5 to 10 a).

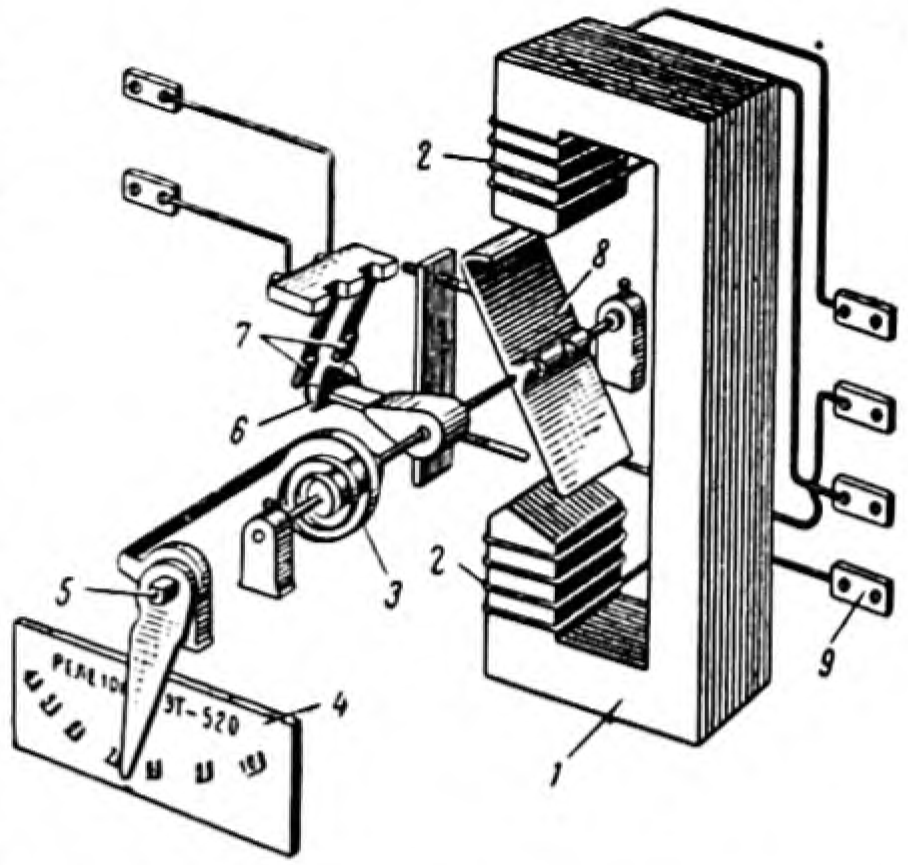


Fig. 258. Schematic diagram of type ЭТ (ET) electromagnetic overcurrent relay.

For an inverse-time overcurrent relay the time-current characteristic is the name given to a graph showing how the time required for the relay to operate depends upon the value of the current passed through its sensing element (coil); its time setting is the adjustment made in the timing mechanism to make it operate within a definite interval expressed in seconds.

Indirect-Acting Relays, In modern protective relaying it is wide practice to use both indirect-acting electromagnetic overcurrent relays type ЭТ (ET), and indirect-acting induction overcurrent relay type ИТ (IT).

An electromagnetic overcurrent type ЭТ (ET) relay (Fig. 258) consists of magnetic core *1* on the protruding poles of which is arranged a set of windings *2*. The relay also comprises a pivoted spindle to which are attached armature *8*, moving contact bridge *6* and spiral restraining spring *3*, secured at one end to the spindle and at the other end to adjusting indicator arm *5*. In addition, the relay incorporates stationary operative-current contacts *7* (for connection in the operative-power circuit), current-setting scale *4* and a set of terminals *9* for interconnection of the relay windings and inserting the relay into the actuating circuit. These relays are enclosed in a moulded-plastic case with a glass window opposite the scale.

When a current passes through the windings, armature *8*, due to magnetic attraction, strives to come under the core poles, but is held back by restraining spring *3*.

However, when the current reaches a value equal to the current setting, the torque developed by the armature exceeds the resisting torque of the spring and the armature turns towards the poles to cause contacts *6*

and *7* to close on each other, i. e., the relay operates.

After the circuit breaker associated with the relay is tripped open, the flow of current to the relay windings is cut off, armature *8* is returned by spring *3* to its initial position and contacts *6* and *7* reopen. By altering the tension of spring *3* with adjusting indicator *5*, any desired current setting can be made on scale *4*. By changing from series connection of the windings to parallel connection, the required operating current can be raised by two times, as the windings of the relay permit of series and parallel connection.

The operating time of the above type of relay is of the order of several hundredths of a second.

An induction relay with an inverse-time characteristic such as the ИТ (IT) relay (Fig. 259) consists of two elements: an induction and an electromagnetic element.

Common for both elements are the following: relay winding *22* with taps brought out to tap plate *20* provided with two tap-contact screw plugs *21*, operative contacts *16*, a shiftable current-setting indicator (not shown) and terminals *15* for connection to the actuating circuit.

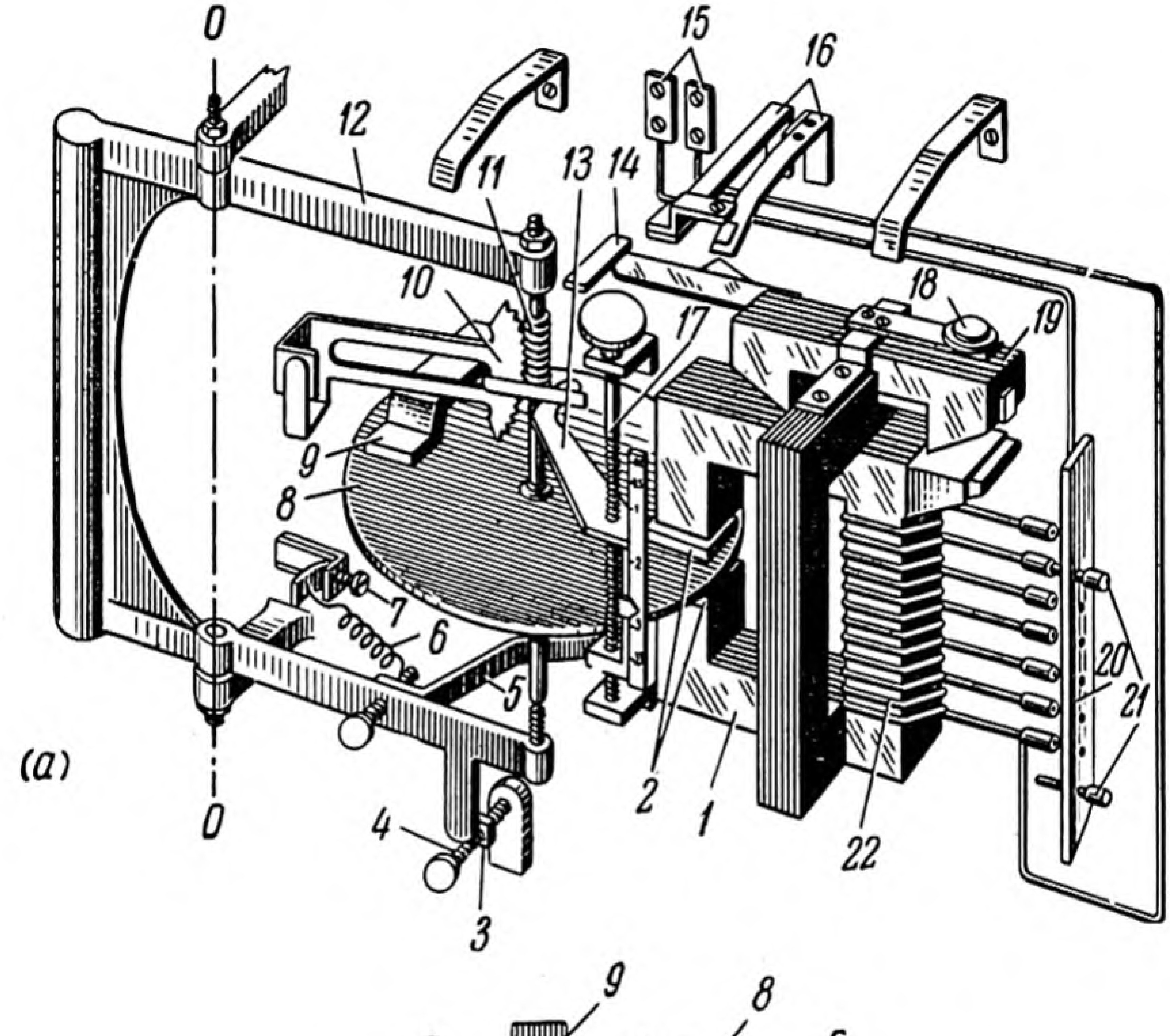
The relay operates in the following way. If the value of the current passing through the relay winding circuit equals 20 to 30 per cent of the current setting, disk *8* begins to rotate, but the relay will not close contacts *16* because pivoted frame *12* is held back in its extreme position by spring *6* and worm *11* on the disk spindle is kept out of engagement with toothed sector *10*. The disk turns in the clockwise direction and is acted upon by two forces F_1 and F_2 (Fig. 259*b*). Force F_1 is created by magnetic system *1*, force F_2—by permanent magnet *9*. Both of these forces strive to swing disk *8* and pivoted frame *12*, as a whole, towards toothed sector *10*, but are counteracted by restraining spring *6*.

When the current passing through the relay winding reaches the operating current setting, forces F_1 and F_2 overcome the resistance of spring *6* and turn pivoted frame *12*, together with the disk and its spindle, so that worm *11* is brought into engagement with toothed sector *10*. Sector *10* begins to rise and, after a definite interval of time, causes the finger attached to its end to press against the left-hand end of rocking arm *14* and raise it. This decreases the air gap between the protrusion of core *1* and armature *19*. The latter, quickly attracted to the core, shorts contacts *16* by bridging them with rocking arm *14*.

When the frame is turned towards the core, steel arm *5* is attracted to the core to provide engagement of the worm with the toothed sector.

As was stated earlier, rise in current in the winding creates a greater force. This makes the disk rotate faster, increases the

rate at which the toothed sector rises and thus shortens the time required for the induction element to operate. However, the magnetic system begins to saturate. At this point the speed of the disk does not increase any further and the time of operation then becomes dependent on the distance which the toothed sector must go through from its initial position, i. e., in



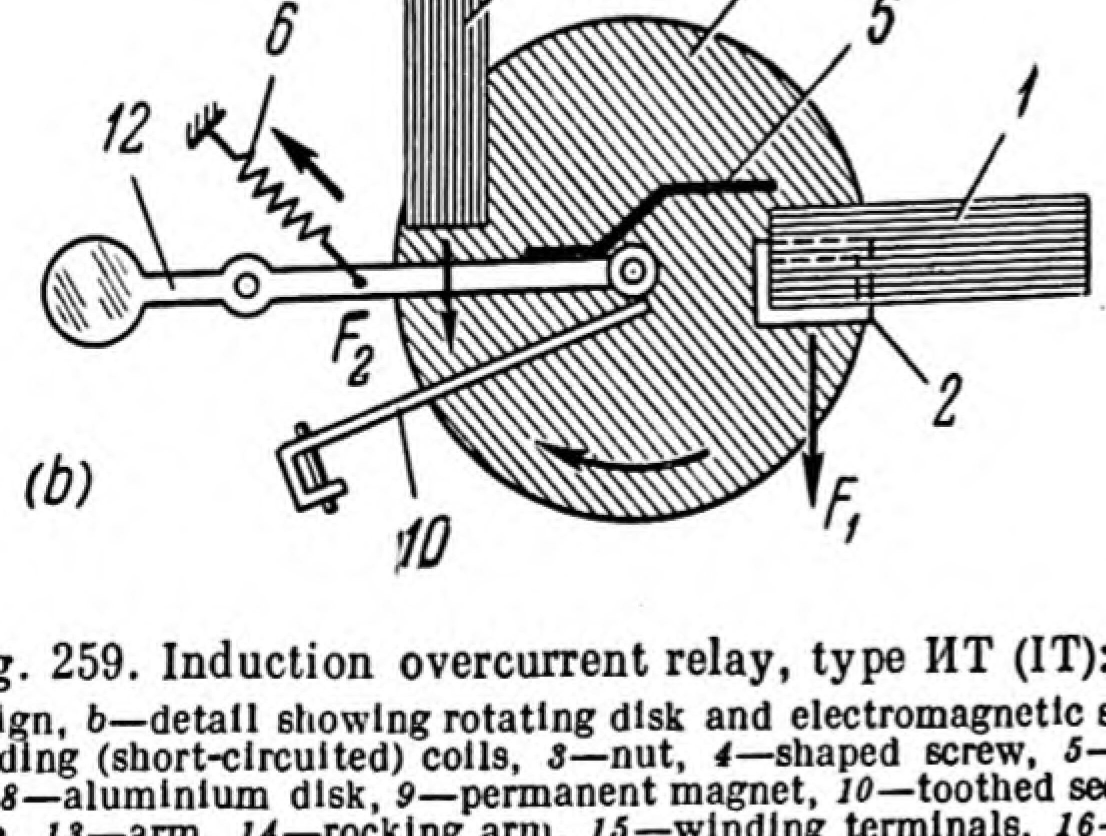


Fig. 259. Induction overcurrent relay, type ИТ (IT):

a—features of design, *b*—detail showing rotating disk and electromagnetic system; *1*—magnetic core, *2*—shading (short-circuited) coils, *3*—nut, *4*—shaped screw, *5*—steel arm, *6*—spring, *7*—screw, *8*—aluminium disk, *9*—permanent magnet, *10*—toothed sector, *11*—worm, *12*—pivoted frame, *13*—arm, *14*—rocking arm, *15*—winding terminals, *16*—operative contacts of relay, *17*—time-setting screw, *18*—current cut-off setting screw, *19*—steel armature, *20*—tap plate, *21*—tap-contact screw plugs, *22*—relay winding.

this case the relay will operate with a time lag independent of the current.

The total time of operation of the relay can be adjusted with the aid of screw *17* which shifts arm *13* to set the initial position of toothed sector *10* and thus adjust its angle of turn.

If a current strong enough to suddenly attract armature *19* to the core is passed through the relay, the operation of the latter becomes instantaneous. This action of the electromagnetic element is termed *overcurrent cut-off* or simply *cut-off*.

The operating current of the induction element is adjustable over a range from 4 to 10 amperes, adjustment being accomplished by inserting contact screw plugs *21* into the necessary nest in tap plate *20*.

The overcurrent cut-off setting is made by changing the air gap between armature *19* and core *1* with setting screw *18*.

Direct-Acting Relays. Direct-acting relays such as types PTM (RTM) and PTB (RTV), also called built-in relays, are incorporated or built into a circuit-breaker operating mechanism (as, for example, in a type ПРБА (PRBA) or some other operating mechanism).

A schematic diagram showing the main parts and connections of a type PTM (RTM) relay (designation meaning overcurrent relay with instantaneous response) is given in Fig. 260. The operation of this relay is based upon the electromagnetic properties of a solenoid.

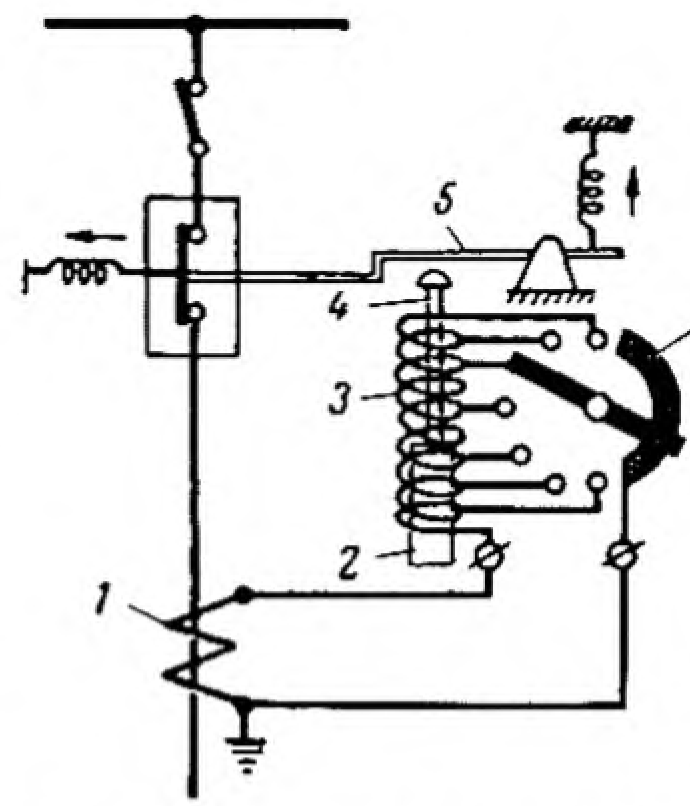


Fig. 260. Schematic diagram showing the main parts and connections of type PTM (RTM) direct-acting overcurrent relay.

Relay winding *3*—a solenoid—is connected to the secondary winding of current transformer *1*. When a current equal to or greater than the value of the current setting flows through the relay winding, plunger *2* is pulled into the solenoid. This causes striker *4* of the plunger to hit trip lever *5* in the circuit-breaker operating mechanism, unlatch the mechanism and allow the circuit breaker to trip open.

As soon as the current stops to flow in the disconnected line, the current in current transformer *1* ceases and the relay plunger drops back.

The above relay has a turns-selector switch *6* to change the number of active turns in the relay and provide current settings of 5, 7, 9, 11, 13 and 15 amperes.

The type PTB (RTV) relay—designation meaning overcurrent

relay with time delay—is designed similar to the PTM (RTM) relay, but incorporates a clockwork mechanism which prevents the striker from travelling upward instantaneously. The striker moves more gradually in accordance with the run-down of the clockwork mechanism. This type of relay has current settings of 5, 6, 7, 8, 9 and 10 amperes.

Auxiliary-Type Protective Relays

The relays which in protective schemes perform auxiliary or secondary operations are of the electromagnetic class. Their windings are energised at a certain constant value of current or voltage (supplied from the operative power source).

Such relays are available with windings designed for energising by a-c or d-c operative supply.

The designs and types of such relays are extremely diverse. Below will be discussed only some of the most widely used designs.

Time-lag relays (Fig. 261) serve to introduce independent time delays in the action of a relay protection.

When a current is passed through winding *1* of the electromagnet arrangement, armature *23* is attracted inward, finger *17* loses its support and toothed sector *13*, under the force of spring *8*, begins to turn in the clockwise direction. This leads to counterclockwise movement of gear wheel *12* and moving contact *11*. The latter, when it reaches stationary contacts *10*, shorts them. As a result, the operative circuit of the relay is closed and the relay has performed an operation.

Gear wheel *12* is fitted on a spindle which is connected by friction clutch *6* to a clockwork mechanism (parts *7*, *5*, *4*, *2*, *16*, *3*, *14*, *15*) to make the

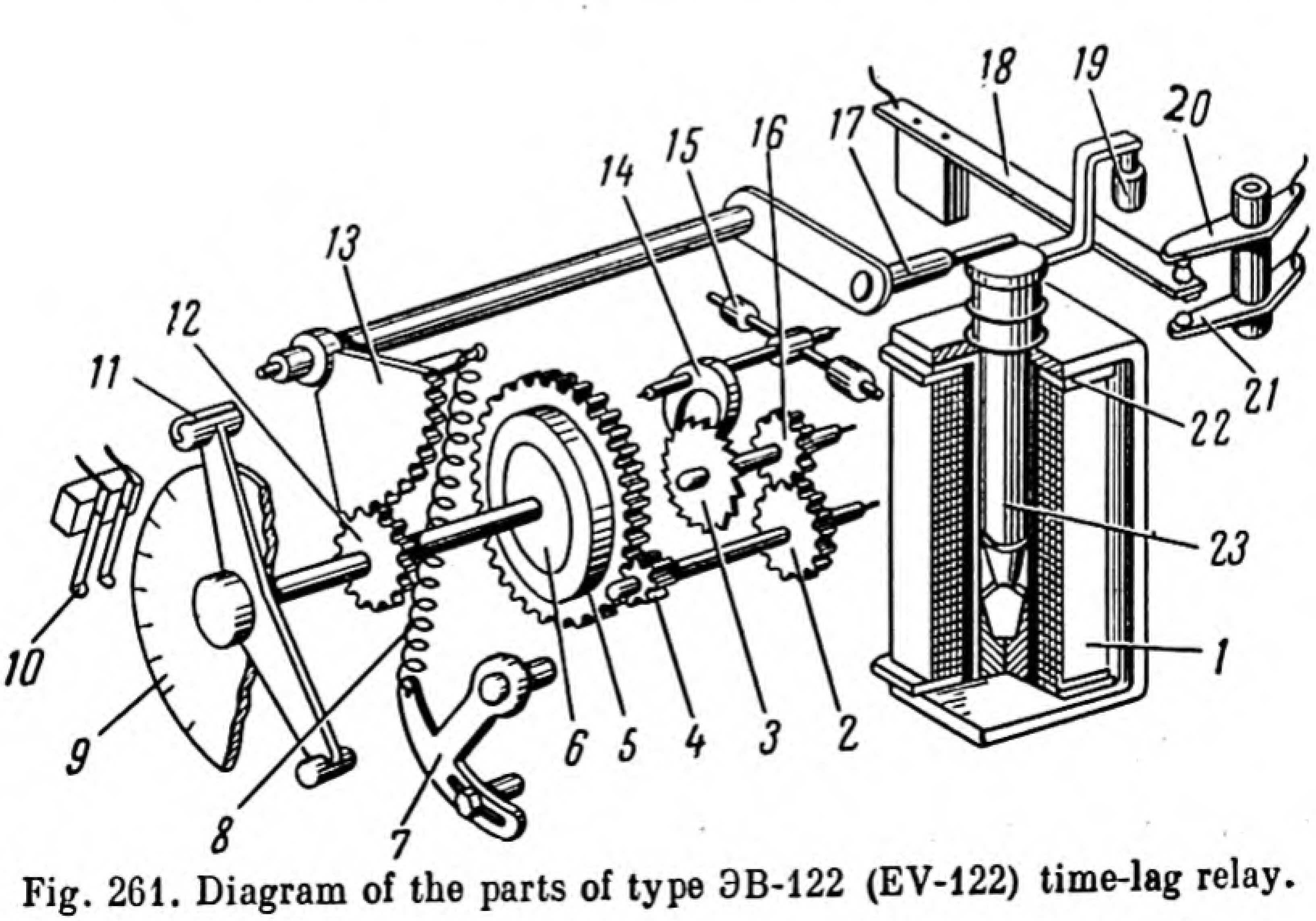


Fig. 261. Diagram of the parts of type ЭВ-122 (EV-122) time-lag relay.

moving system of the relay revolve at a constant rate of speed.

When the current ceases to flow through the electromagnet coil, the core of the magnet is raised by return spring *22* and the entire moving system of the relay quickly goes back to its initial position (resets).

The time interval after which the relay must operate (time-delay setting) is adjusted by changing the initial distance between moving contacts *11* and stationary contacts *10*. To make a required time-delay setting, the block on which contacts *10* are mounted is shifted along scale *9* and fixed opposite the respective scale division. The time-setting scale is marked in seconds. This relay is also furnished with a set of instantaneous contacts consisting of parts *18*, *19*, *20* and *21*.

Signal relays. Signal relays (Fig. 262) are used to signal the operation of various elements in a given protective relay scheme. Simultaneously with target drop-out, they close circuits which energise electric alarm signals (visible and audible).

When a current is passed through coil *2* of such a relay, its core *1* attracts armature *8* to release target *7* from the raised position it has been held in by armature *8*. Target *7*, pivoted on a spindle, drops to a position opposite glass window *6* in the cover of the relay. Fixed on the same spindle with the target is moving contact *4*. It also turns when the

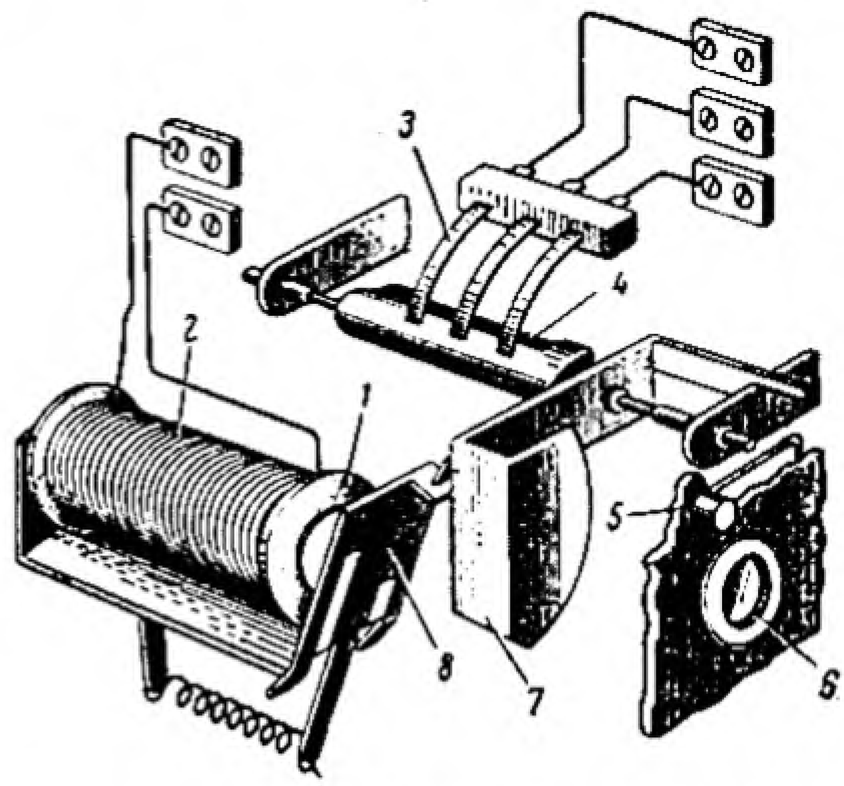


Fig. 262. Parts of an ЭС (ES) electromagnetic signal relay.

target drops and shorts stationary contacts *3* connected to the operative circuits of the signalling alarm system. By means of reset knob *5* provided on the relay cover, the target and contacts can be reset after each operation of the relay.

These relays are available for either series or parallel connection to relay operative circuits.

Auxiliary relays. Auxiliary relays serve primarily to relieve the low-capacity main-relay contacts of the duty of handling large operative currents and also to multiply one received actuating pulse into a number of pulses fed into several other circuits. An auxiliary relay such as the type ЭП (EP) relay has an electromagnetic system and a multi-contact control element with relatively high-switching-capacity contacts, some of which serve to make circuits and others to break them.

The U.S.S.R. relay type designations stated above have the following meanings: the first

letter indicates the operating principle of the relay; the second letter—the quantity to which the relay responds; the numbers—the code to indicate the modification of the relay. For example: ЭТ-500 (ET-500) indicates that the relay is an electromagnetic-system overcurrent relay; ЭВ-181 (EV-181)—an electromagnetic-system, time-lag relay for d. c.; ЭВ-201 (EV-201)—an electromagnetic-system, time-lag relay for a. c.; ЭП-101 (EP-101)—an electromagnetic-system auxiliary relay for d. c.; ИМ-141 (IM-141)—an induction-system power relay.

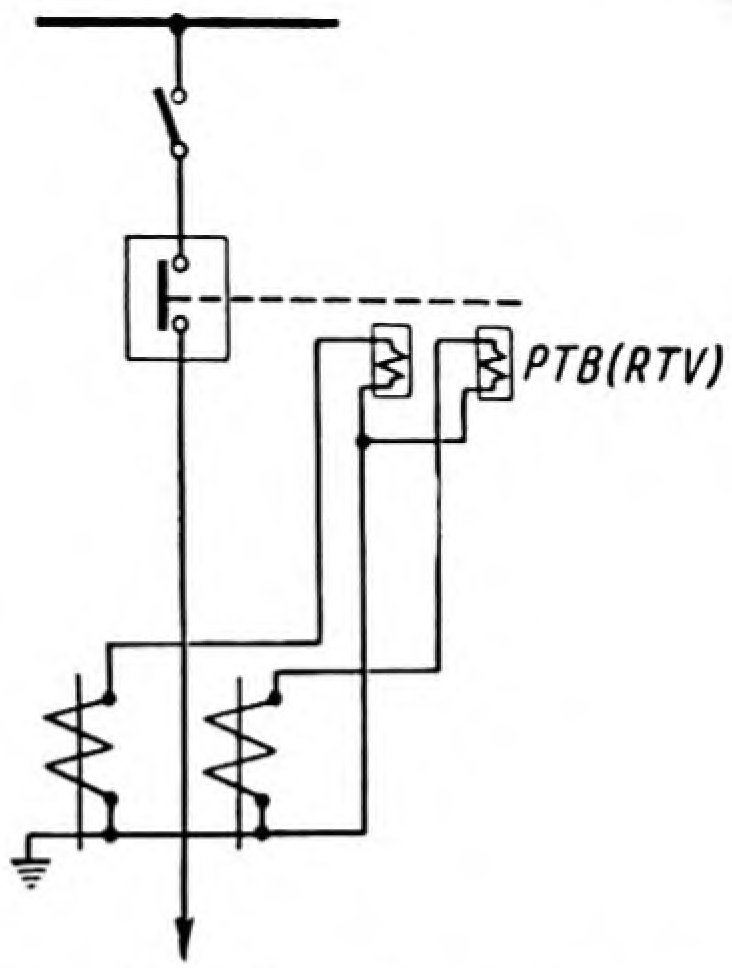


Fig. 263. Two-phase overcurrent protection scheme using type PTB (RTV) direct-acting relays.

3. The Principle of Overcurrent Protection

In 6- and 10-kv electric power installations it is wide practice to protect the overhead and cable lines, power transformers and motors by means of an overcurrent relay protection, most simply and at the lowest cost accomplished by means of direct-acting, built-in type PTB (RTV) overcurrent relays.

The protection scheme for a two-phase overcurrent protective arrangement can be seen in Fig. 263. This scheme will operate in the event of any kind of phase-to-phase short circuit. If, however, the phase in which the current transformer has been excluded is faulted to earth, no current will be obtained for flow through one of the relay coils. The above protection therefore fails to operate in such cases.

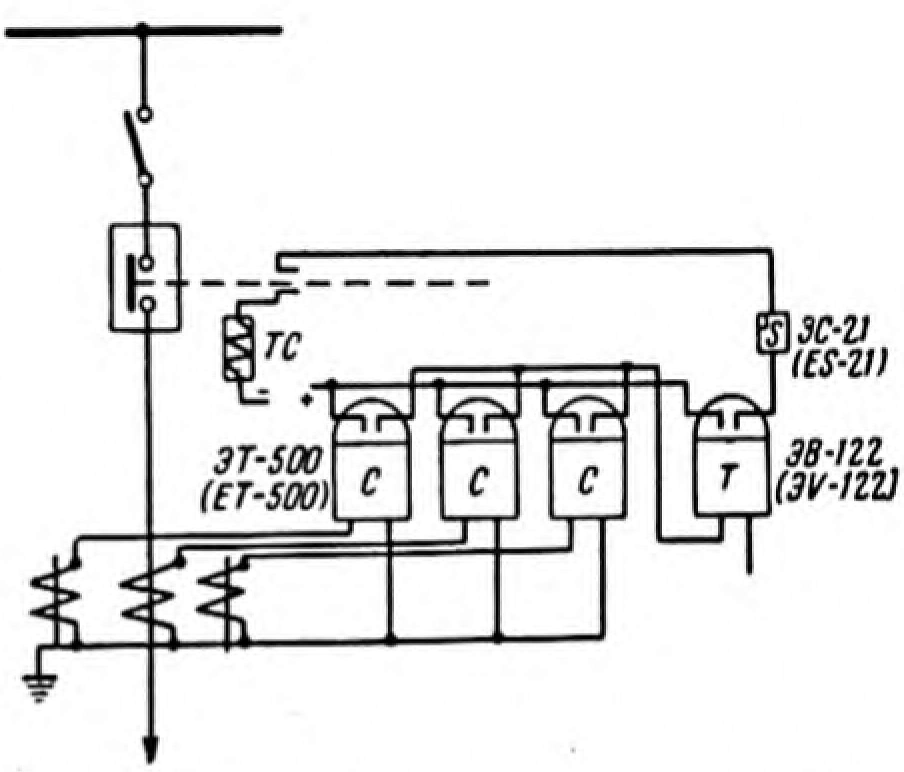


Fig. 264. Three-phase overcurrent protection scheme using d-c operative power supply, type ЭТ-500 (ET-500) electromagnetic overcurrent relays, and type ЭВ-122 (EV-122) electromagnetic time-lag relay.

Fig. 264 shows a three-phase overcurrent protection scheme incorporating independent time delay and designed for d-c operative power supply. This protection uses type ЭТ-500 (ET-500) overcurrent relays and an ЭВ-122 (EV-122) time-lag relay.

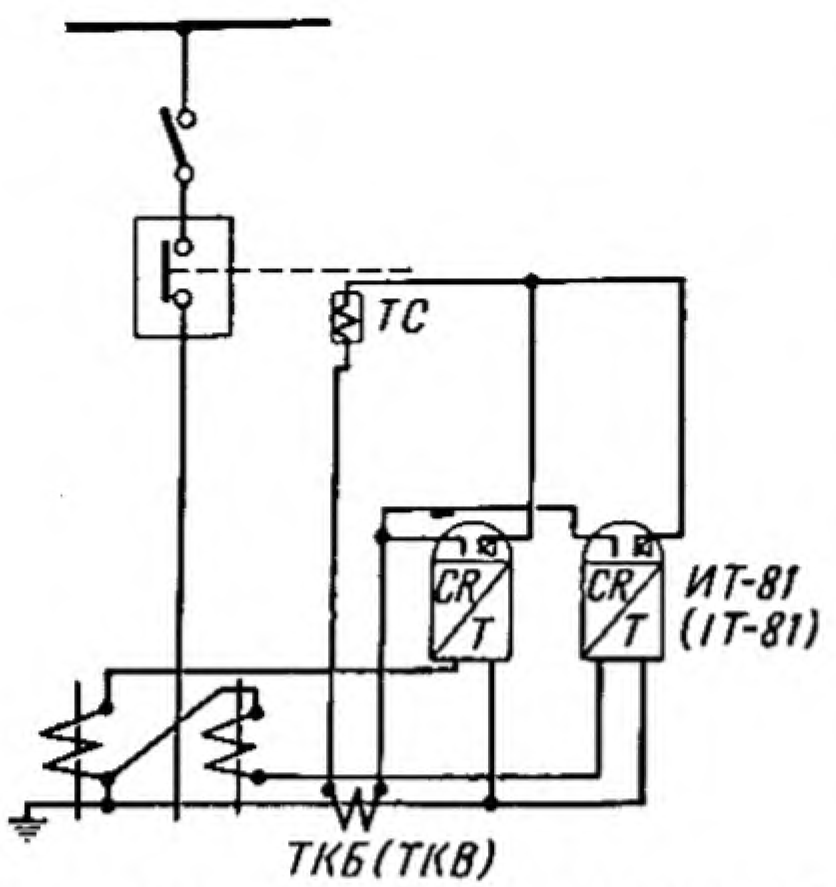


Fig. 265. Two-phase overcurrent protection scheme using type ИТ-81 (IT-81) induction relays and a-c operative current obtained from a ТКБ (ТКВ) quickly-saturable intermediate current transformer.

A protection such as the above will operate in the event of all kinds of short circuits and also when a fault to earth occurs.

Fig. 265 shows a two-phase protection scheme using type ИТ-81 (IT-81) induction, inverse-time, overcurrent relays. An intermediate type ТКБ (ТКВ) current transformer serves to furnish the operative power in this protection scheme.

The cross-sectional area of the ТКБ (ТКВ) current transformer core has been made just large enough to cause the core to be quickly saturated by the magnetic flux. The primary of this transformer is to be connected in the secondary-winding circuit of the main current transformers.

Due to quick magnetic saturation of the core, the current in the secondary of a ТКБ (ТКВ) intermediate current transformer will not exceed 8 to 12 amperes, a current level quite easily handled by the contacts in the type ИТ-81 (IT-81) induction relay.

When the current rises to a certain value this relay will provide instantaneous operation by means of its overcurrent cut-off element.

In multi-branch power cable circuits a special earth-fault current transformer (Fig. 266) is used for setting up current protection against single-phase faults to earth. This transformer has a ring core with one secondary winding. Such a transformer is slipped over the end of the three-core power cable to be protected and its secondary winding is connected to a current relay. The primary winding in this case is the cable itself.

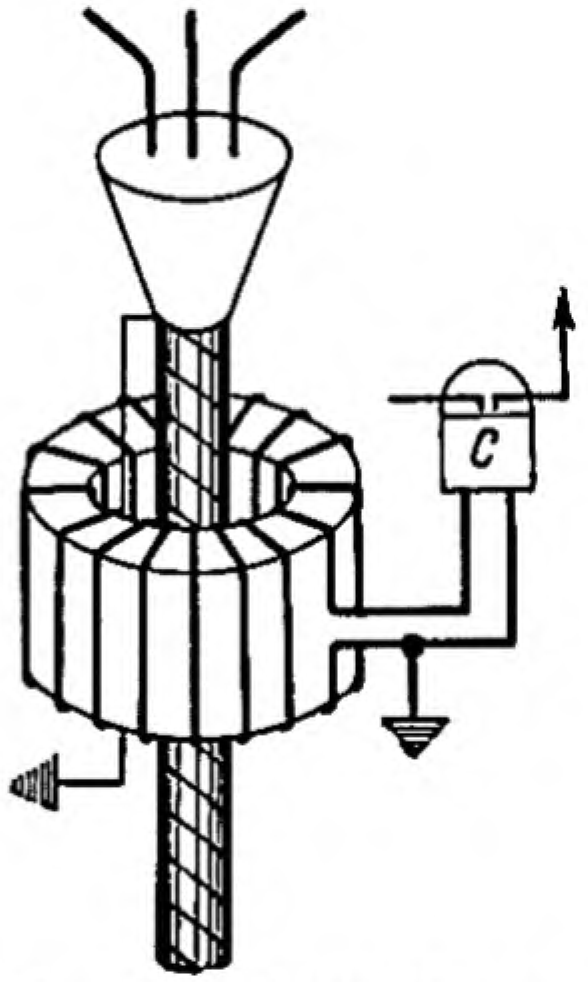


Fig. 266. Scheme for protecting cable line from single-phase faults to earth.

Under normal operating conditions, during periods of overload, and in the event of interphase short circuits, the vector sum of the currents flowing in all the three phases remains equal to zero and, therefore, no magnetic field will be able to appear around the cable to induce a current in the transformer for flow through the relay winding.

When a fault to earth occurs, the symmetry of the currents flowing in the cable is disturbed and a magnetic flux appears in the space around the cable and in the transformer core. This induces an e.m.f. in the secondary winding, there is a flow of current through the relay winding and the relay will operate.

4. Signalling and Interlocking

In the high-voltage circuits of operating substations, the circuit connections or arrangements must be quite frequently changed. In order for the duty attendant to know how the circuits are connected at any given moment of operation, and what changes have occurred, for example, an abnormal condition of operation, a system of visual and audible signalling is used. The most widely practised forms of signalling are:

1) signalling to show the position of the contacts of operative station apparatus (of the circuit breakers, isolators);

2) alarm signalling to show emergency trip-out of circuit breakers;

3) warning signalling to warn of the appearance and the nature of an abnormal operating condition.

A system of interlocks is incorporated to prevent isolators from being improperly operated. For example, it prevents any opening and closing of the isolators when the circuit breakers associated with them are closed.

Circuit-Breaker Position Signalling. The position of circuit breakers (Fig. 267) at any given instant is shown by indicating lamps placed in special indicating lamp fittings capped with coloured light filters. Where manual operating mechanisms are used, the indicating lamps are mounted near the circuit breaker operating mechanism. In remote-control installations the indicating lamps are mounted on the control board panels, each set near the control switch for the given circuit-breaker operating mechanism.

When a circuit breaker is open, its green indicating lamp burns; if it is closed, the red indicating lamp burns. Indicating lamps receive their supply

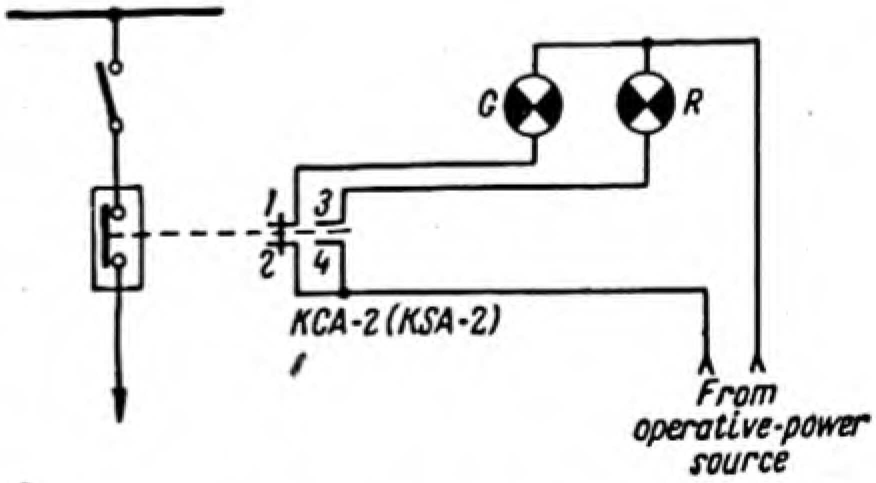


Fig. 267. Circuit for signalling the position of a circuit breaker.

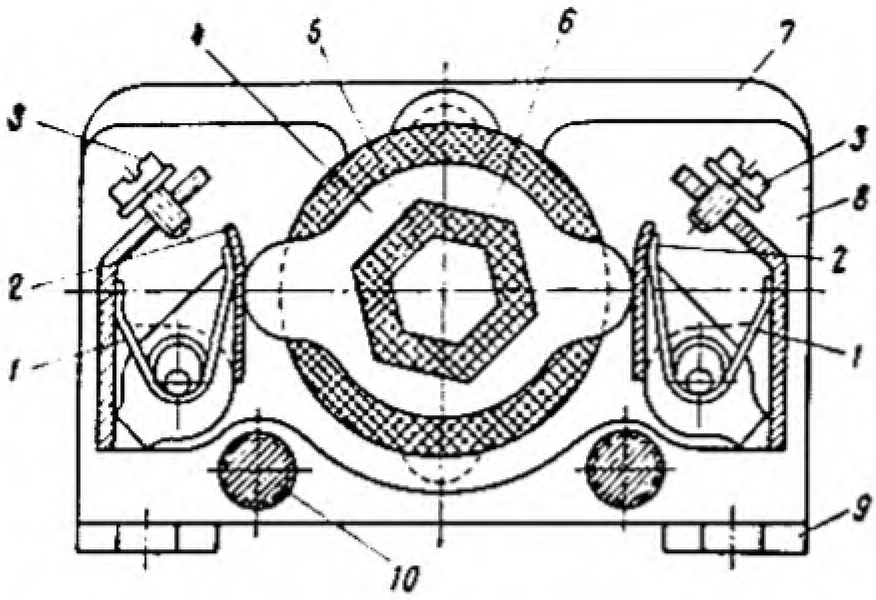


Fig. 268. Section through one circuit of a type KCA (KSA) auxiliary switch:
1—spring, *2*—stationary contact, *3*—terminal screw, *4*—moving contact, *5*—shaft, *6*—moulded-plastic washer, *7*—pressed-steel case, *8*—moulded-plastic separator block, *9*—foot for securing the case, *10*—strain studs for securing set of contact sections.

from the operative-power source through signalling-interlocking contacts in the form of an auxiliary switch mechanically linked to the circuit-breaker operating mechanism.

Type KCA (KSA) auxiliary switches (Fig. 268) take the form of a case within which are arranged sets of contacts for controlling two, four, six or more circuits.

Each set consists of two stationary spring-backed contacts *2* fitted with terminals *3* for connection of the wiring.

Between each pair of stationary contacts, mounted on common shaft *5*, is a moving contact *4* in the form of a copper ring provided with protrusions and embedded in moulded-plastic washer *6*. When the moving contact is turned by the shaft to its horizontal position, the ring protrusions interconnect the stationary contacts with each other. The shaft extends beyond the case and is fitted with a lever linked to the circuit-breaker operating mechanism by a tie bar.

From the circuit diagram in Fig. 267 we see that when the circuit breaker is in its open position contact pair *1* and *2* is bridged and the green indicating lamp burns. When the circuit breaker closes, the circuit between contacts *1* and *2* is broken and contact pair *3* and *4* becomes bridged; this results in the green indicating lamp going out and lighting up of the red indicating lamp.

Warning Signalling. Such means are provided in substations where attendants are constantly on duty. They serve to warn of excessive temperature rise in any of the power transformers, of oil leakage from a transformer tank, of internal faults in a transformer, of single-phase faults to earth, of appearance of overloads and of deviations from normal operating conditions in the various parts of the given electrical installation.

The signalling system circuits are generally designed to be common for the entire installation. Closing of these circuits is performed by signal relays which energise a warning alarm bell. The instant the warning bell begins to ring, the duty attendant, by seeing which signal relay has shown its target, establishes the cause of disturbance, switches the audible signal over to the visible signal by means of the audible-warning throw-over switch, and takes

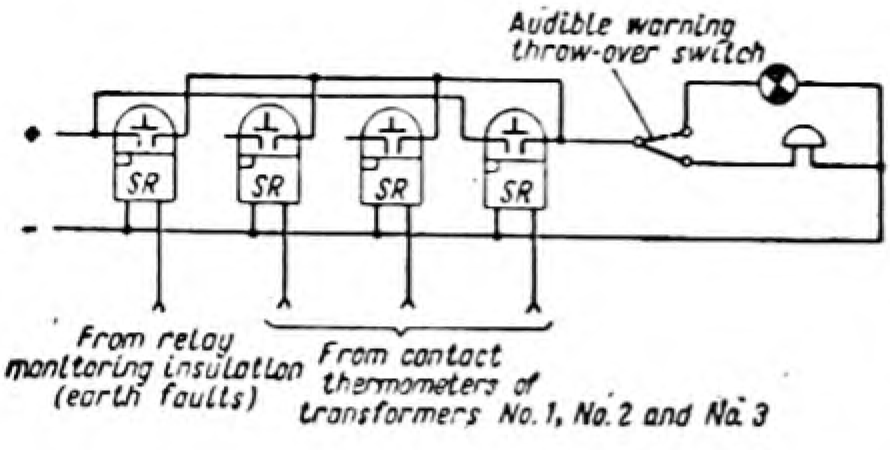


Fig. 269. Diagram of warning signal circuit.

the necessary measures to remedy the trouble.

Fig. 269 shows a warning-signalling circuit used to warn of single-phase faults to earth and of excessive temperature rise in any one of three transformers.

Fig. 270 shows an insulation monitoring scheme for a high-voltage circuit. It uses a three-phase, five-limb type НТМИ (NTMI) voltage transformer provided with an additional secondary winding.

In accordance with the way this circuit is designed to act, the appearance of a fault to earth in any one of the phases causes a voltage to appear in the voltage-transformer secondary winding connected to relay *VR*. The latter operates and closes the signalling circuit.

It should be noted that under normal operating conditions all three voltmeters *V* connected to the other secondary winding indicate the phase voltages in the installation. When one of the phases becomes shorted to earth, the voltmeter in the earth-faulted phase reads zero; the other two voltmeters read full line voltage.

After being warned of the existence of a fault to earth, the duty attendant determines which phase has been faulted by a glance at the readings given by the voltmeters.

Interlocking Against Improper Operation of Isolators. Since isolators are not designed with arc-extinguishing devices, they must be opened and closed after the power circuit has been broken by a circuit breaker. Therefore, an isolator must be closed prior to the closing of a circuit breaker and be opened after the circuit breaker has been opened.

To prevent any other sequence of operation, a special mechanical or electromagnetic interlocking arrangement is used to eliminate any possibility of carrying out an isolator operation sequence other than the correct one.

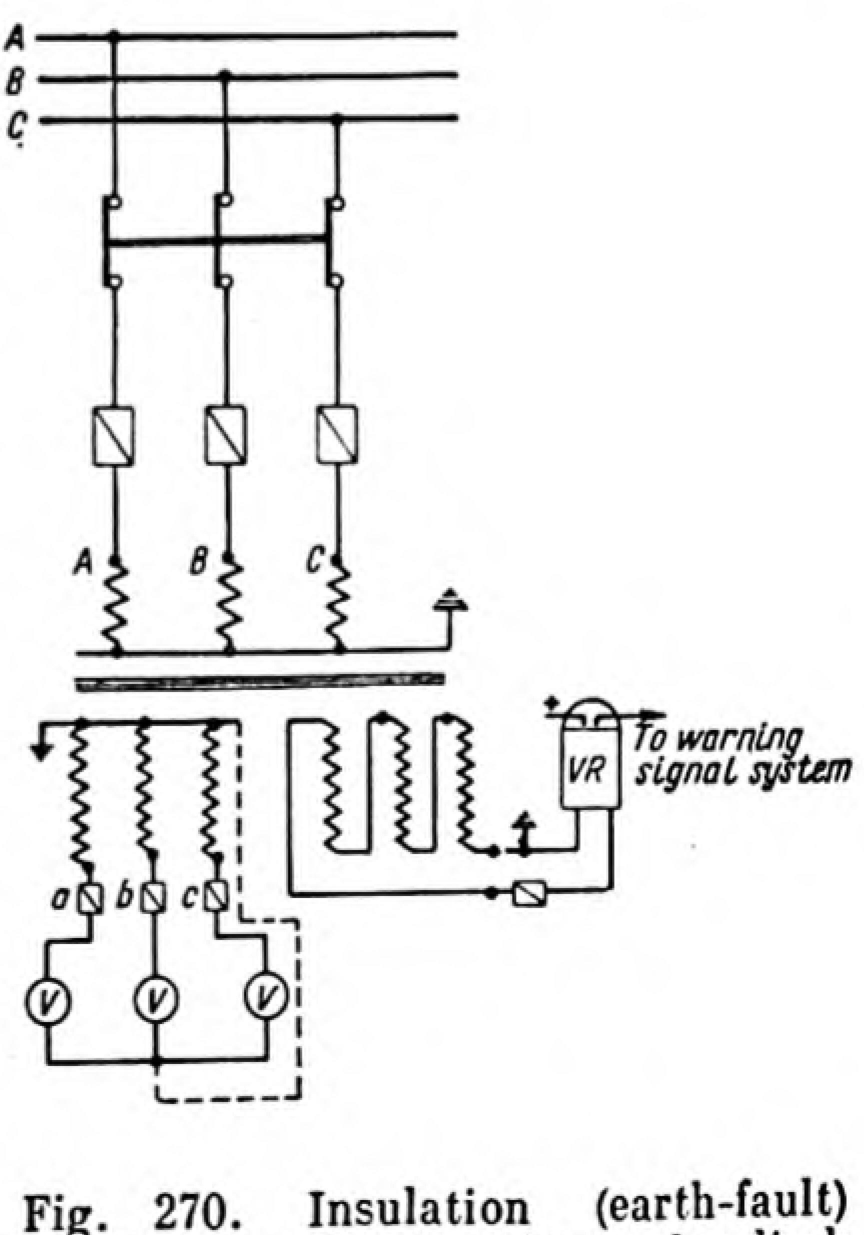


Fig. 270. Insulation (earth-fault) monitoring scheme using a five-limb voltage transformer with two secondary windings.

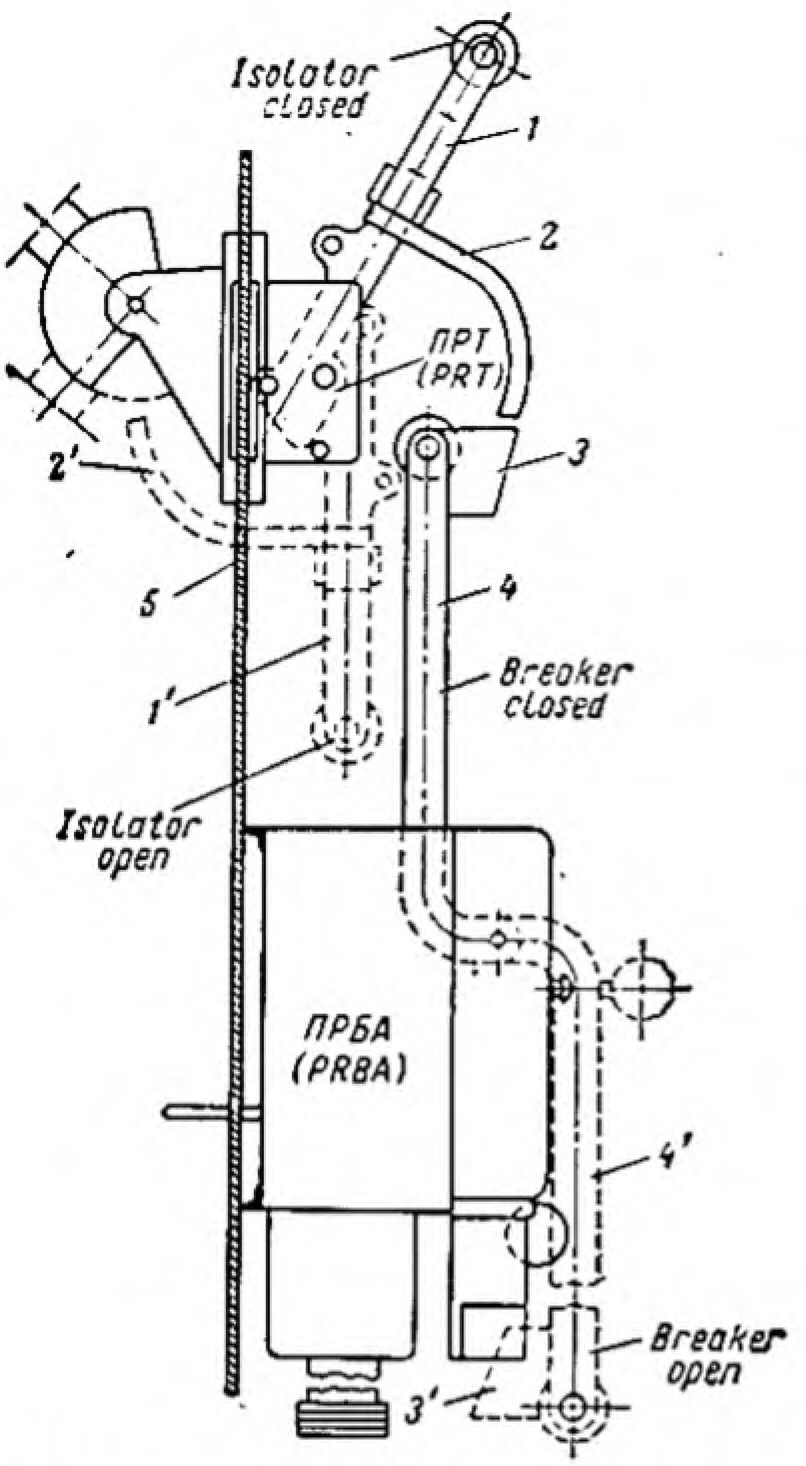


Fig. 271. Schematic diagram of mechanical interlocking arrangement.
Note: 1', 2', 3' and 4' indicate the open positions of the isolator and circuit breaker.

A schematic diagram of a mechanical interlocking arrangement is shown in Fig. 271. This figure shows that the isolator can be swung open after the circuit breaker has been opened. If the circuit breaker has not been opened, lever arm *1* of the isolator operating mechanism will be unable to turn downward because spur *2* and stop lug *3* do not permit of such movement. In this arrangement the spur is welded to the isolator operating mechanism lever and the stop lug is welded to circuit-breaker operating lever *4*.

The isolator can only be closed when the circuit breaker is in its open position. If the breaker is closed, the circuit-breaker operating mechanism lever arm prevents any turning of the isolator operating-mechanism lever arm.

When the lever arm of the isolator operating mechanism is swung downward, spur *2* can pass through a special hole *5* provided for it in the cubicle wall.

One of the forms of an electromagnetic interlocking arrangement is schematically represented in Fig. 272. The main parts in this arrangement are latching unit *3*, built into the isolator operating mechanism, and a portable electromagnetic key *5* fitted with winding *4*.

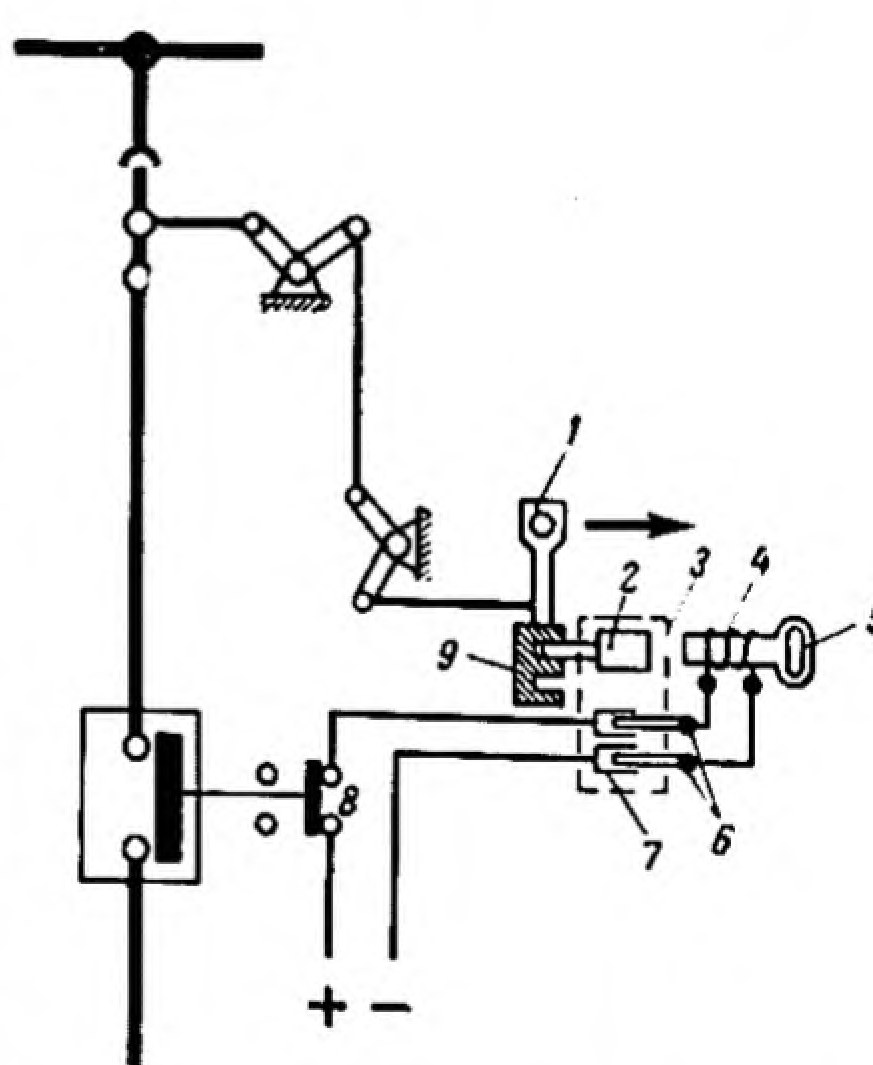


Fig. 272. Electromagnetic interlocking arrangement.

Latching unit *3* keeps, through plunger *2*, the turning part of lever arm *1* in the operating mechanism locked in. The latching unit also contains socket contacts *7* which are connected through interlock contacts *8* of the circuit-breaker operating mechanism to the 110-or 220-volt d-c operative power source.

If the key is inserted into the latching unit when the circuit breaker is in its open position, key contact pins *6* enter socket contacts *7* and a current will flow through the key winding. The plunger part will then be attracted to the key to unlock the latch and permit the isolator to be opened.

When the circuit breaker is closed, the circuit through which the key winding receives a supply current is broken at interlock contacts *8*. The key core therefore cannot attract the plunger and leaves the latch in its locked position, making it impossible to open the isolator.

When the isolator is brought into its open position, plunger *2* slips into opening *9* and prevents the isolator from being closed until its operating mechanism latch has been unlocked. This can only be achieved after the circuit breaker has reached its open position.

An electromagnetic interlocking arrangement can thus exclude any possibility of opening or closing of an isolator when the circuit breaker associated with it is closed.

Chapter IX

ERECTION OF SWITCHGEAR INSTALLATIONS FOR VOLTAGES OVER 1,000 VOLTS

1. Work Performed in Mounting Apparatus and Main Electrical Equipment for Indoor Switchgear Installations of the On-Site-Installed Type

Laying Out and Marking Off. The work of laying out and marking off for installing the equipment of an indoor switchgear installation of the on-site-installed type can be illustrated by the example of one outgoing-line cell of a switchgear installation put in according to the single-line main connection diagram given in Fig. 273 and to the main dimensions speci-

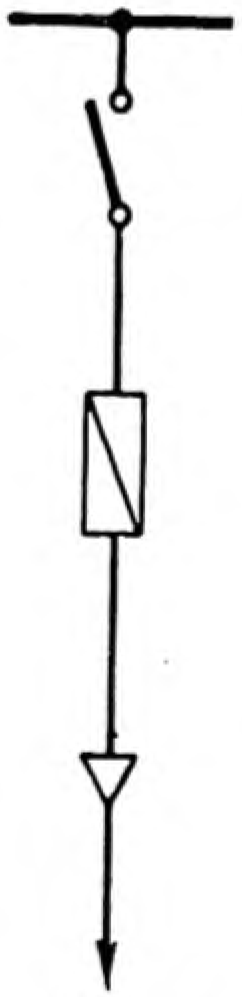


Fig. 273. Single-line diagram of an outgoing line.

fied in the sectional views shown in Fig. 274. Knowing the dimensions of the cell, its main vertical mounting axis *A-B* can be laid out and marked off. For this, dimension *ab* is taken from the working drawing and laid off strictly horizontal on the rear wall between partitions and at the top part of the cell. This gives us point *A* (Fig. 275). A plumb line, first powdered with chalk or Prussian blue, can now be suspended at some distance above point *A* so that the line hangs vertically directly opposite point *A*.

As soon as the line stops swinging, it is pressed against the rear cell wall and snapped to beat off vertical axis *A-B*.

Following this, the necessary horizontal axes *1-1*, *2-2*, *3-3*, *4-4* and *5-5* (Fig. 275) are measured, marked and beaten off with the use of a colour-coated string.

The horizontal axes must be perpendicular to the main layout axis. Their perpendicularity is simplest to check with a triangle.

After the vertical and horizontal axes have been marked off, the places at which the separate units of equipment are to be fixed must be marked off. Since the cell walls are usually plaster finished, and the floor is given a finishing coating which raises it above the unfinished floor lever, measuring off should be done from screeding marker surfaces which give the true subsequent finished levels of the walls and the floor.

Installation of Fixing Parts and Support Metalwork. To anchor the fixing parts by which support metalwork is secured to the structural surfaces, the necessary through and blind holes must be driven.

The pneumatic hammer is the most productive tool for hole driving. However, when a small amount of work is to be performed, its cost of operation will be uneconomical because a special compressor unit is required to furnish it with compressed air. Furthermore, air-hammer tools are convenient only for driving large holes in thick walls. Such tools are not good for making small holes in thin walls because they are too destructive in action.

Today the holes in the brick and concrete surfaces of indoor switchgear installations are driven by means of electric hand drills fitted with carbide-tipped drill bits.

When holes are driven in concrete, the use of electric drills incorporating speed reducers designed to give a drilling speed of 500 rpm is recommended.

Hole driving by purely hand methods is also practised. However, such methods, even where the amount of work to be done is small, can not be considered rational because of their low productivity.

For cemented-in anchor studs and bolts, the diameters of blind holes are taken equal to 5-6 stud or bolt diameters.

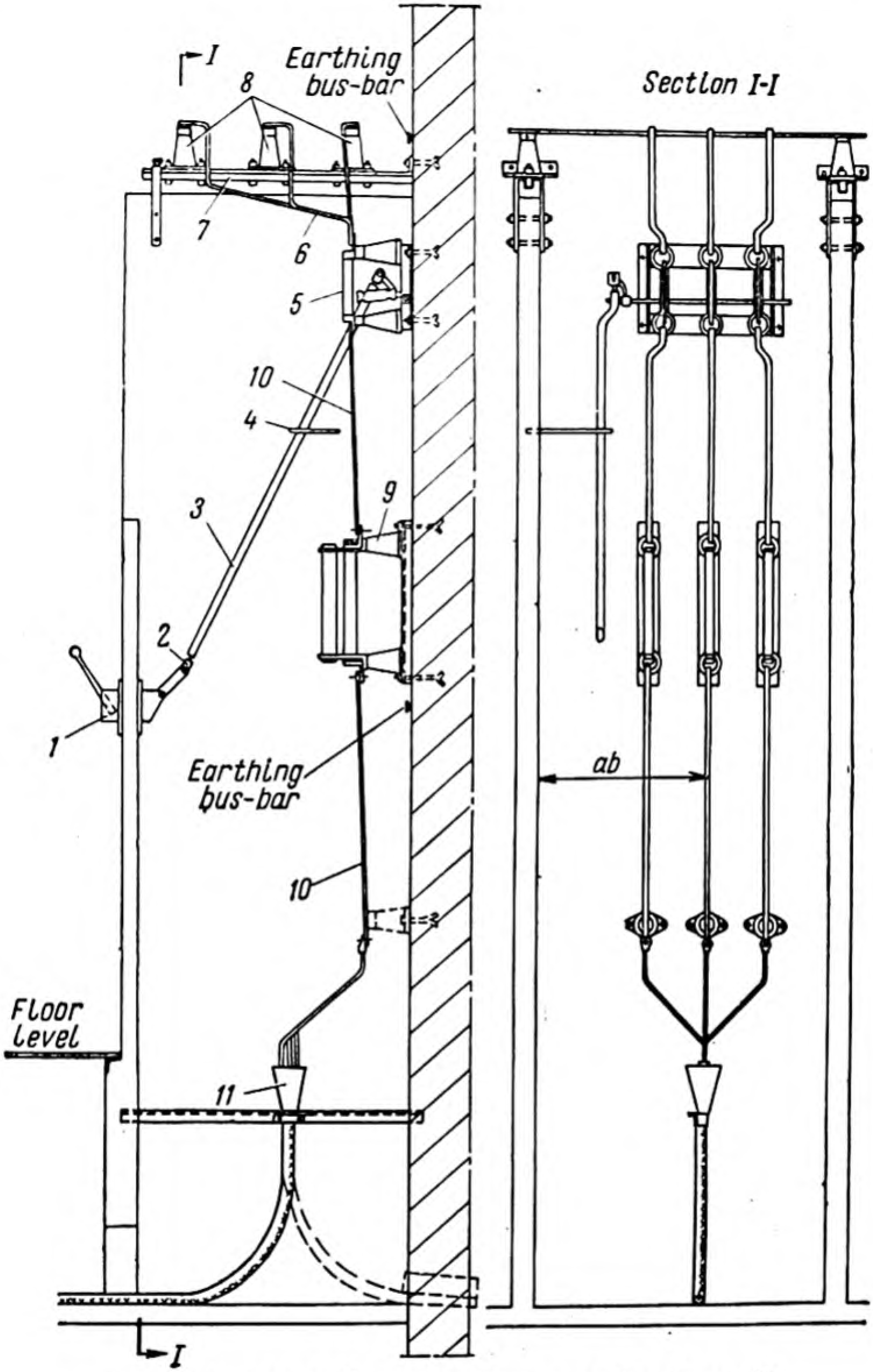


Fig. 274. Sectional views of an outgoing-line cell:

1—isolator operating mechanism, 2—tie-rod adjusting clevis, 3—steel-pipe tie rod, 4—safety stirrup, 5—three-pole isolator, 6—tee-off bus-bars, 7—metalwork for main bus-bar support insulators, 8—post-type support insulators, 9—ПК (PK) quartz sand-filled fuses, 10—connection bus-bars, 11—cable sealing end.

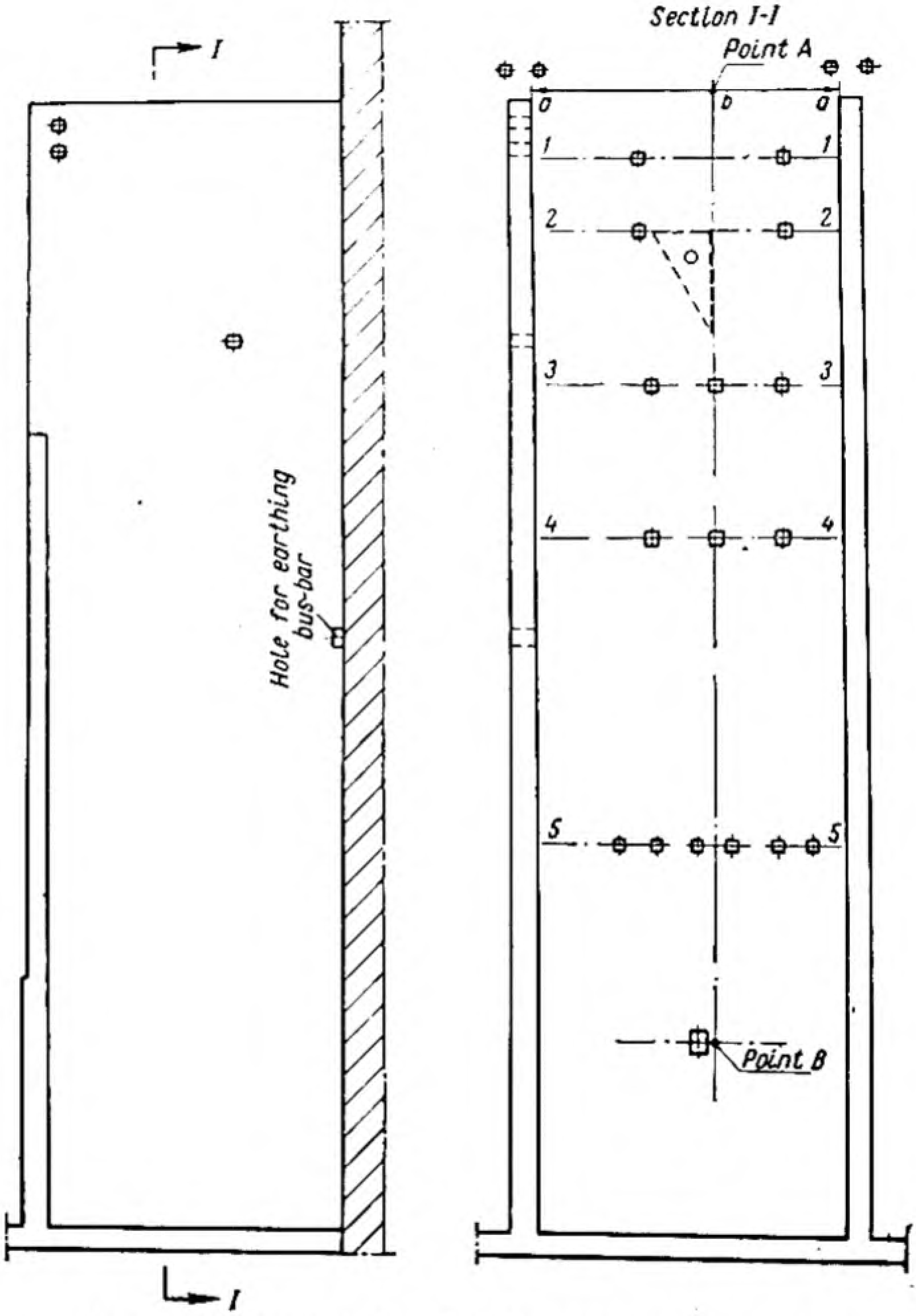


Fig. 275. Layout drawing for outgoing-line cell.

The depth of blind holes for cemented-in anchor studs or bolts is made equal to 8-10 outside diameters for studs or bolts up to 5 mm in diameter and to 10-12 outside diameters for anchor studs or bolts of greater diameter. Through holes for bolts and studs passed through walls should be driven with a diameter 1.5 to 2 times the bolt or stud diameter.

To pass an angle iron member through a wall, the hole should be driven so as to have each of its sides about 1.5 to 2 times greater than the corresponding leg of the angle iron.

Blind holes for cementing in the feet of undersupport metalwork made of angle iron should have a depth of 120 to 150 mm, and each side of such a hole should be 1.5 to 2 times greater than the corresponding leg of the angle iron.

Grouting-in of fixing parts and undersupport metalwork is done with a cement-sand mortar consisting of 1 part of cement and 2 to 3 parts of sand when anchor studs or bolts are grouted in and with a cement-sand mortar of 1 part of cement, 2 to 3 parts of sand and 1 part of small size gravel when undersupport metalwork and heavy anchor or foundation bolts are grouted in.

Switchgear apparatus and equipment can be mounted on their fixing parts and undersupport metalwork 7 to 10 days after grouting in. However, the mortar takes 20 to 25 days to acquire full strength.

Each hole prepared for the above parts is first thoroughly cleaned of remaining particles of brick or concrete and dust, and then wetted with water. The ready mortar is next forced into the hole with a trowel, first thoroughly coating the hole surfaces, and then fully filling the hole with mortar, taking care to tamp the mortar well in with the trowel.

The following operation consists in driving the stud, bolt, metalwork or stirrup leg into the mortar-filled hole with light blows of a hammer. If the part to be driven into the mortar has a threaded external end (a stud or bolt, for example), a nut should be screwed over the threaded end or a cushioning pad held on top of it to receive the blows of the hammer and protect the threads.

The mortar forced outward when the part is driven in must be tamped back into the hole with a trowel. If studs or bolts are being cemented in, they are next checked for proper positioning with a template.

When stirrups and support metalwork assemblies are cemented in, they must be checked with a spirit level and plumb line to see that they are truly level and vertical. They should also be checked for proper positioning.

Mounting of Post Insulators and Bushings. On brickwork or concrete walls post insulators are fixed either with through bolts or studs (Fig. 276*a* and *b*), or with cemented-in anchor studs

(Fig. 276c). In the majority of cases they are fixed on under-support metalwork members constructed from angle iron or strip steel.

Bushings may be directly mounted in wall- or floor-structure openings by fixing them with through bolts or studs, or on steel or reinforced-concrete plates, or on sheet steel backed by an angle-iron frame grouted into the necessary openings (Fig. 277).

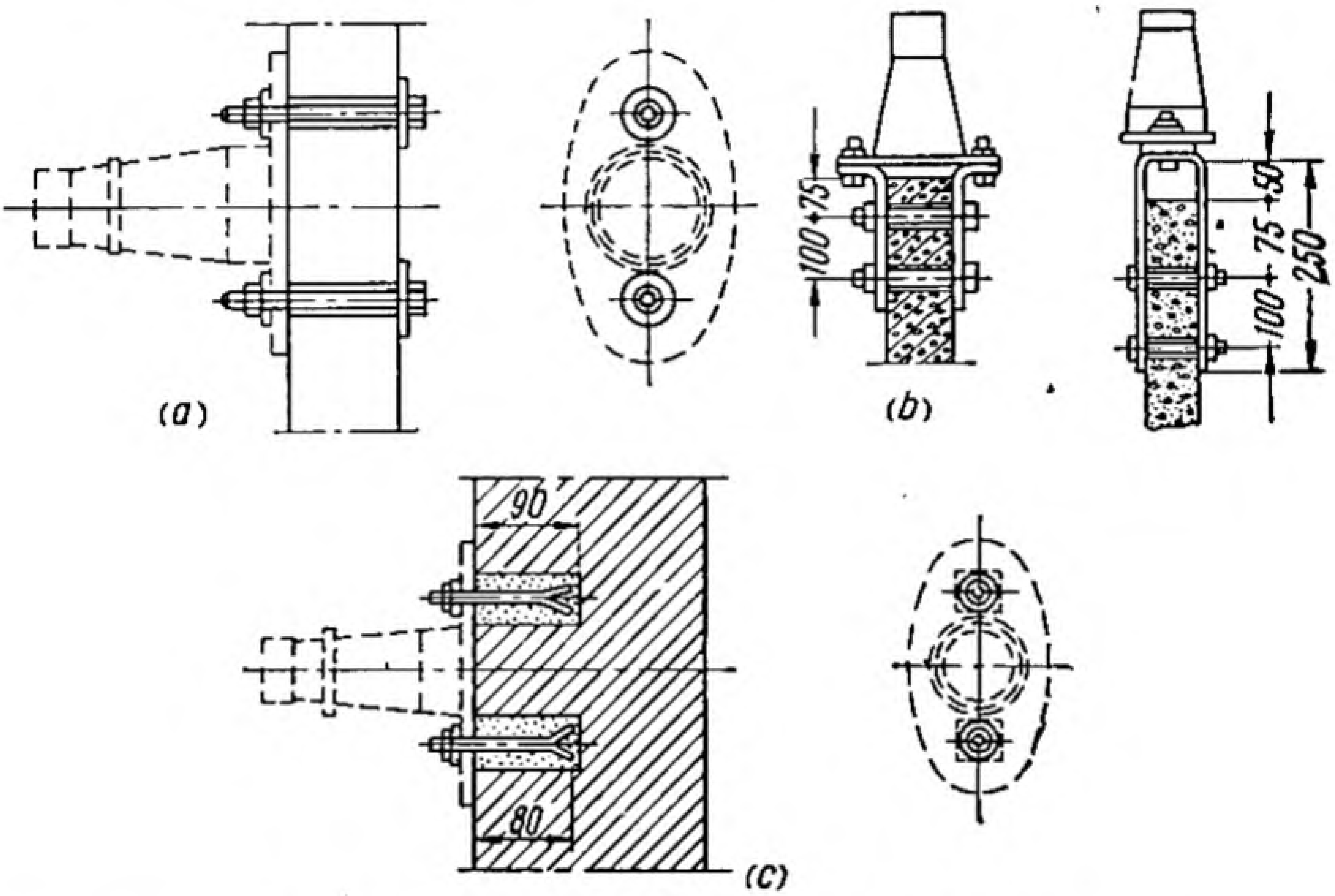


Fig. 276. Examples of post insulator fixing:
a—with through bolts to cell partition, b—on metal undersupports, c—with cemented-in anchor studs.

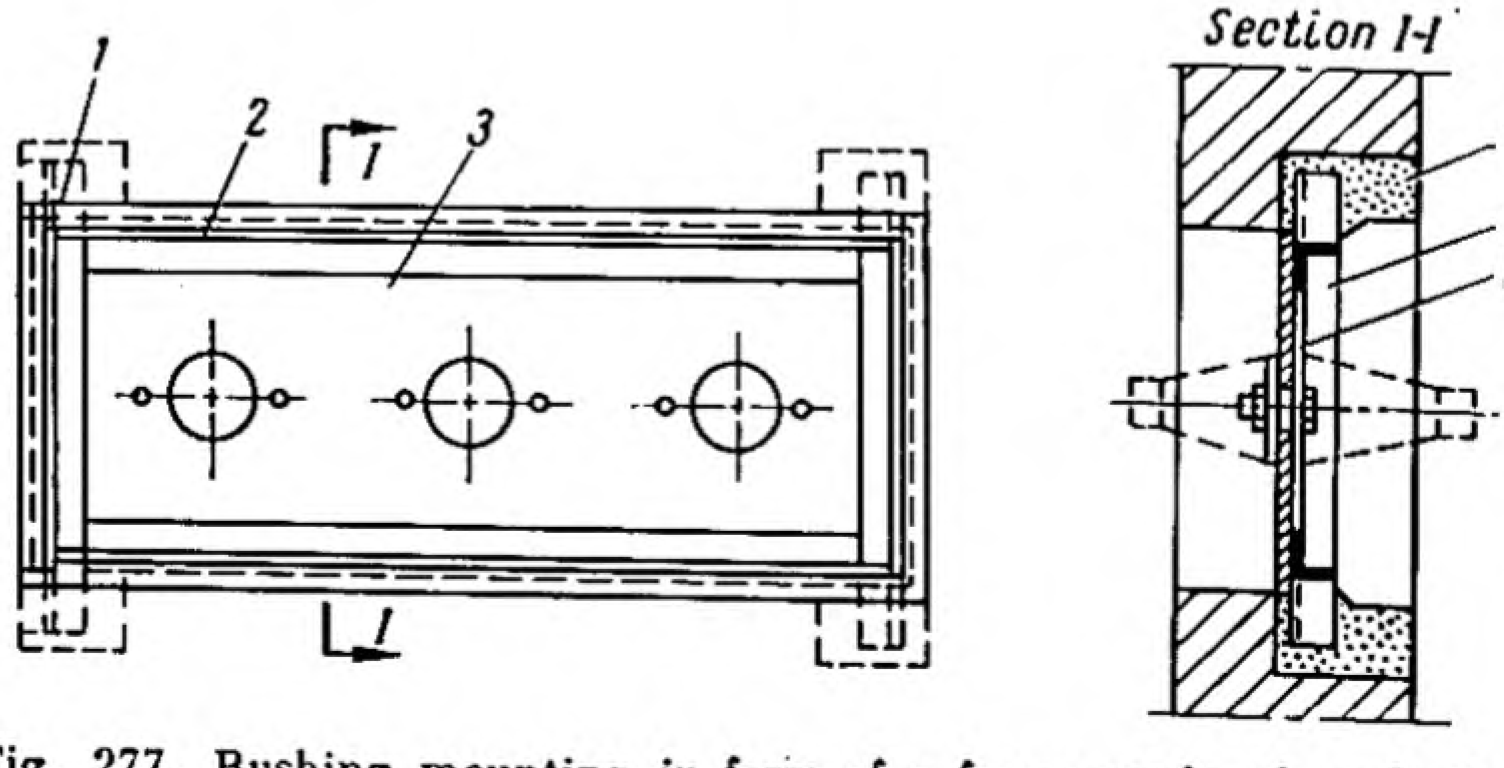


Fig. 277. Bushing mounting in form of a frame made of angle iron:
1—part of frame which is grouted in, 2—angle-iron frame, 3—steel cover plate.

The axis of any type of insulator must always fall in line with the marked-off transverse and longitudinal axes.

Each set of insulators should be mounted so that the top surfaces of their cap fittings are strictly at the same level. Insulators should be so arranged that all the earthing bolts face in the same direction and provide the shortest connection to the main earthing bus-bars.

When mounting post insulators, the insulators are fixed first at the ends of the straight runs of each phase and then a cord, thin steel cable, or wire is stretched from one end to the other. All the intermediate insulators can be mounted after this in full alignment with the longitudinal axes.

The horizontal alignment of parallel runs of post insulators is checked with a straight-edge bar and spirit level (Fig. 278). Levelling of the post insulators is done by inserting thin steel shims under their bases during fixing.

When post insulators are mounted on metalwork undersupports, they are easy to space in lines at a given distance from each other because of the oval holes or transverse-slot construction provided in the undersupports.

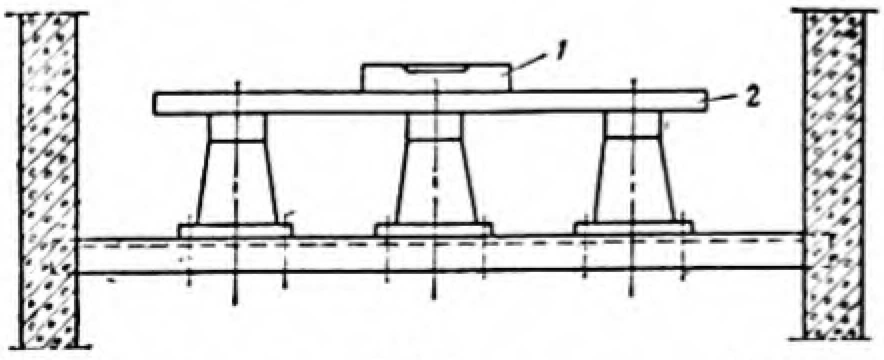


Fig. 278. Levelling a row of post insulators with a spirit level (*1*) and a straight-edge bar (*2*).

For obtaining adequate electrical contact between the insulator base and support metalwork (required for subsequent earthing), both the bottom face of the insulator base and the seating surface on the metalwork must be cleaned to a bright finish, and also coated with petroleum jelly or a neutral grease to protect them against corrosion.

Mounting of Isolators and Their Operating Mechanisms. When isolators require mounting in the lower part of a cell, they are usually lifted by hand. Isolators which need to be secured at the top of a cell are generally lifted with block and tackle.

Each isolator, after being lifted into position, is fixed and simultaneously aligned with the cell axes (see Fig. 274).

Isolator contact operation must be adjusted so that:

a) the isolator knives close smoothly and without bumping action when the knives meet with the stationary contacts;

b) the angle through which the isolator knives travel to reach their open position is equal to that prescribed by the isolator manufacturer.

When adjusting for proper angle of knife blade opening (achieved by sector lever setting and change in tie-rod length) check to see that all the knife blades close simultaneously on their contacts. The difference in position by which they fail to make contact simultaneously, for isolators with ratings up

to 10 kv inclusive, should not exceed 3 mm as measured from the closest edge of the stationary contact to the closest edge of the knife blade when measured with a steel rule.

To check for close-fit contacting, use is made of a 0.01-mm thick and 10-mm wide feeler gauge. It should not pass deeper than 4 to 5 mm between the knife blades and the stationary contacts when the isolator is fully closed.

Isolator operating mechanisms are installed at the same time as their isolators, the fixing being done with four bolts, each provided with a spring washer and a lock nut.

After an isolator and its operating mechanism have been fixed in place, they are interlinked with a tie rod made from 3/4" steel pipe. The tie rod is prepared according to a template shaped from steel wire 3 to 5 mm in diameter.

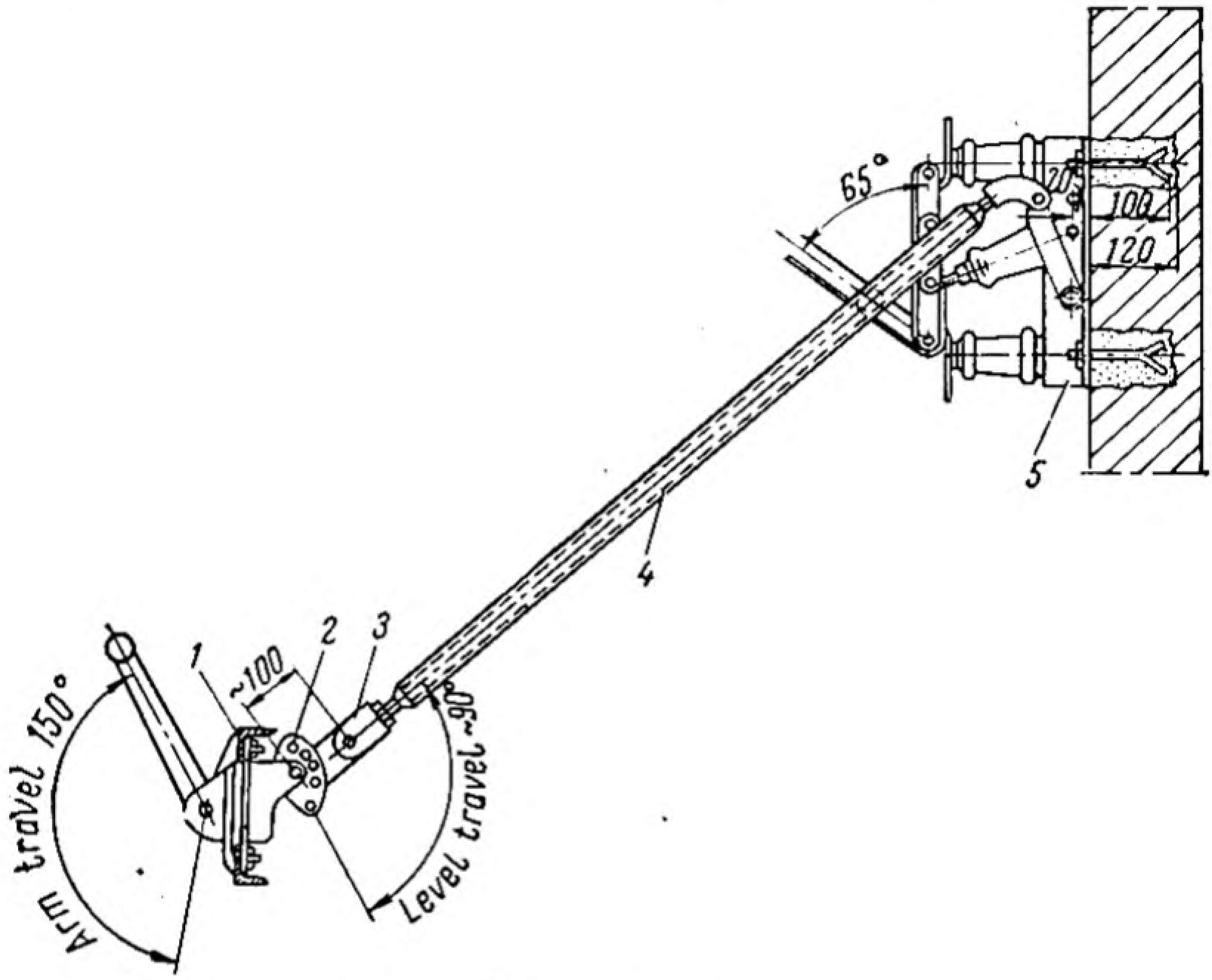


Fig. 279. Isolator linked to its operating mechanism:
1—operating mechanism, 2—sector-shaped lever of operating mechanism, 3—adjusting clevis, 4—steel-pipe tie rod, 5—isolator.

The size and configurations of the templates, and the tie rods made according to them, must conform to those given on the work's erection drawing. To complete a tie rod, clevis end fittings, with their shanks inserted in the trimmed and shaped pipe, are welded on at both ends. The shanks may also be secured in the pipe ends by means of pins. An exam-

ple of the linking of an isolator with its operating mechanism can be seen in Fig. 279.

Circuit Breaker Mounting* (Fig. 280). The first operation performed in mounting a ВМГ-133 (VMG-133) circuit breaker is to lift it, hang it from the two upper M16 anchor bolts and screw nuts on the bolts without tightening them. Following this, the frame is aligned with a plumb line so that it is truly vertical.

If the bottom or top angle-iron support member of the frame fails to fit closely to the wall, the gaps should be filled in by fitting split washers over the bolts between the frame and wall. With the above operation completed and the frame aligned, the nuts on all four anchor bolts can be fully tightened down.

After the frame has been bolted in place, the circuit-breaker shaft must be turned by hand to see that the bearings do not bind, a condition which may arise if the frame is warped (remedied by adjusting tightness of nuts on the anchor bolts).

The next operation consists in filling the oil buffer with clean transformer oil and checking to see that its piston is able to travel with ease.

If the buffer fails to operate satisfactorily, it should be removed from the frame, taken apart and have all its parts washed in clean transformer oil. Its spring and rod end can then be lubricated with petroleum jelly or a suitable grease, the parts reassembled and the buffer put back in place.

The circuit-breaker cylinders can now be hung on the support insulators provided on the frame according to the markings made both on the cylinders and on the support insulator heads. This is done by slipping the cylinder boss-ear over the upper part of the support insulator head and securing the cylinder at the lower end with the clamping bolt.

Before the cylinders are finally secured, they are checked to see that they are vertical, that their geometrical axes fall in one plane with the contact rods and that the distance of $250 \pm \pm 5$ mm is observed from centre to centre between cylinders. After checking, the cylinders are finally secured by screwing the clamping bolts fully in and fixing them with their lock nuts.

The contact rods are connected to their porcelain actuating links and vertical alignment of the rods with the geometrical axes of the porcelain links and the cylinders is checked by eye.

Control of ВМГ-133 (VMG-133) circuit breakers is generally accomplished with a ПС-10 (PS-10) solenoid operating mechanism fixed with four M12 studs screwed into the operating-mechanism body and passed through the cell wall. On the opposite

* In this book we describe the mounting of a ВМГ-133 (VMG-133) oil-minimum circuit breaker, a type widely used within indoor switchgear installations in industrial works.

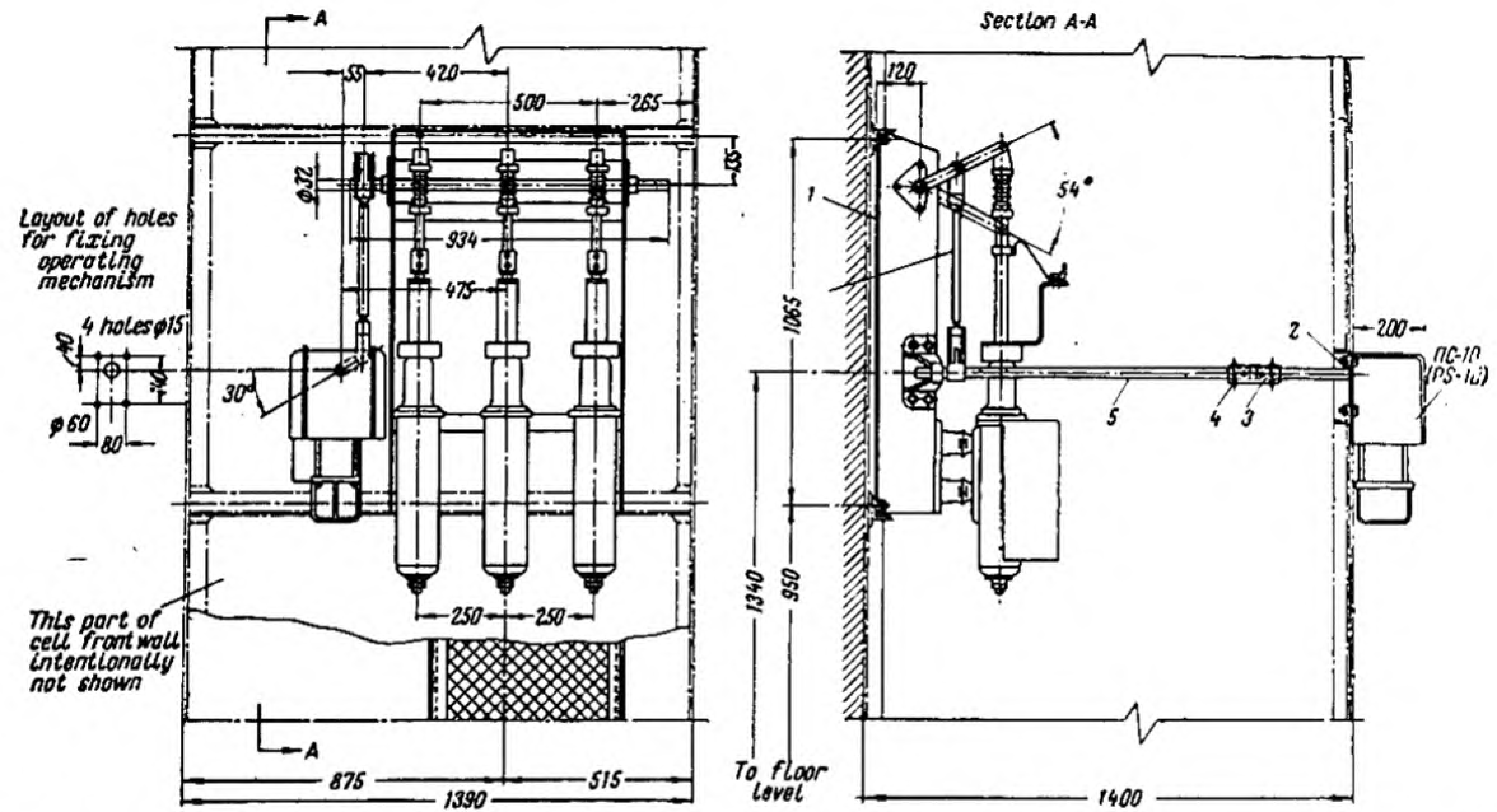


Fig. 280. Erection drawing for installation of a BMГ (VMG) oil-minimum circuit breaker with a ПС-10 (PS-10) solenoid operating mechanism:

1—circuit breaker frame, 2—M12 bolt, 3—coupling sleeve, 4—tapered fixing pin, 5—extension shaft, dia 25 mm, $l = 950$ mm.

side of the wall steel washer pads are slipped over the studs before the fixing nuts are screwed home.

When an operating mechanism is fixed to a cell wall, the hole for its shaft is fitted with a $1^1/_2''$ steel pipe grouted in with cement mortar. Pipe length should equal wall thickness.

As soon as the mounting, alignment and fixing of a circuit breaker and its operating mechanism have been completed, an actuating lever is slipped on to the end of the circuit-breaker shaft extension, the operating mechanism is set in its "closed" position and a lever fitted on to the operating-mechanism shaft at 30 degrees to the vertical. Then, after checking the levers for correct position, they are locked with set screws for final fixing on the shafts. This is accomplished by drilling and reaming the levers and shafts, as assembled, for taper pins in order to pin solidly the levers on the shafts. The operating mechanism is shifted into its "open" position and the operating-mechanism and circuit-breaker levers are linked together with a tie rod and an extension shaft.

The above installation work completed, joint operation of the circuit breaker and operating mechanism is adjusted so that:

1) travel of the contact rods stays within 250 ± 5 mm;

2) rotation of the circuit-breaker shaft is retarded and stopped, as the "open" position is reached, by the middle-phase lever arm meeting the oil-buffer rod head, and, as the "closed" position is reached, by the same lever arm meeting the spring-buffer bolt head;

3) angular displacement of the actuating lever on the circuit-breaker shaft relative to the horizontal axis is the same for both the "open" and "closed" positions;

4) when the circuit breaker reaches its closed position, the spring-buffer spring has an upward deflection equal to 14 ± 1 mm;

5) a clearance of 0.5-1.5 mm remains between the spring-buffer collar washer and the buffer body. If this clearance is too small or has not been provided, shaft rotation during closing will be restricted and the latching member in the operating mechanism will fail to reach required position. Clearance greater than 1.5 mm should be also avoided because in such cases the contact rods will reach an impermissible depth and strike the bottoms of the cluster contacts and break the porcelain links;

6) a spare travel distance of 25 to 30 mm remains below the contact rods. This is needed because the circuit-breaker contact rods have an overreach of about 20 mm beyond their working position during the period beginning with energising of the ПС-10 (PS-10) operating mechanism closing coil and ending with final closing of the circuit breaker.

To check for the existence of the required spare travel

distance, a pencil mark is made on the contact rod at the head of the bushing with the circuit breaker in its closed position. Then, after detaching the contact rod from its porcelain link and allowing it to sink until it reaches the bottom of the cluster contact, a second mark is made in the same manner.

Voltage Transformer Mounting. When mounted within indoor switchgear installation cells, voltage transformers are usually set on angle-iron frame undersupports (Fig. 281), the frame being designed so that the front angle-iron is arranged with its leg pointing downward to make it easy to slide the transformer on and

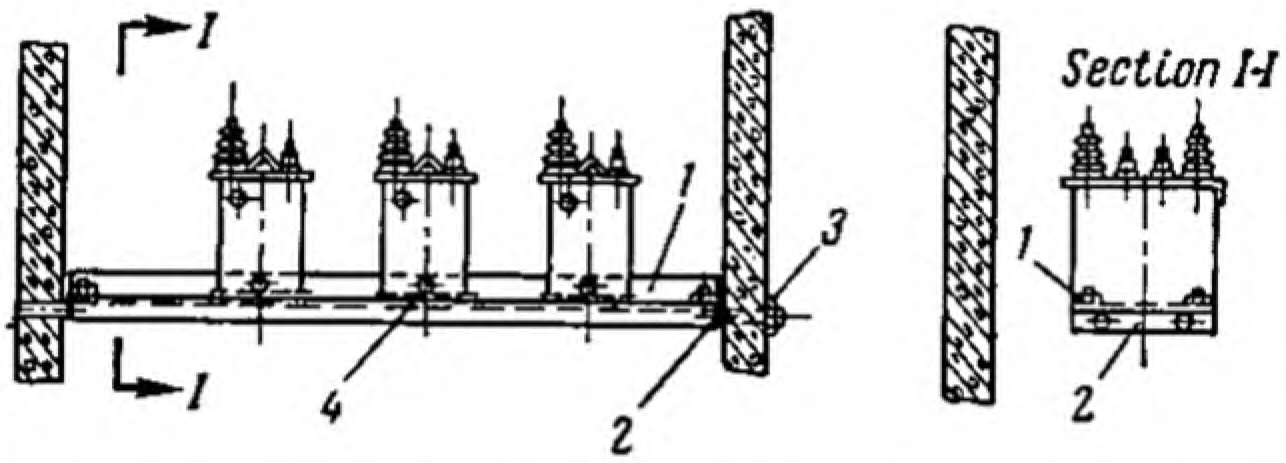


Fig. 281. Voltage transformer mounting:
1—detachable longitudinal angles, 2—detachable transverse angles, 3—through bolts, 4—oil drain plugs.

The distance measured off between the marks will thus equal the spare travel distance.

Contact rod adjustments for adequate spare travel distance are made by screwing the contact-rod tip either further inward or outward.

Current Transformer Mounting. Similar to bushing-type insulators, current transformers may be mounted directly within wall- or floor-structure openings, on angle-iron frame undersupports, and steel or concrete mounting plates. The operations of installing current transformers are the same as for bushings.

When a current transformer is put in, one thing to remember is to arrange it so that the rating plate will be convenient to read.

off both during installation and repair, and, in addition, provide access to the oil drain cock.

Voltage transformers are secured on the angle-iron frames by means of bolts.

Prior to putting oil-immersed voltage transformers into service, the pasteboard sealing washers must be removed from under the oil-filling-hole plugs. This is done to allow the transformers to "breathe" freely.

High-Voltage Fuse Installation (see Fig. 274). The fuse bases are first temporarily secured on anchor studs or bolts and then aligned relative to the given axes of symmetry. Shims of thin sheet steel are used to achieve this. The nuts on the bolts or studs are fully screwed down as soon as proper alignment is attained.

2. *Installation of Bus-Bar Assemblies*

The sequence of operations followed in bus-bar selection, straightening, cutting, bending and installation is listed in the operation-sequence card given in Table 30.

The sequence prescribed in Table 30 is based on bolt jointing of the bus-bars, the method most generally used. However, new methods now acquiring acceptance consist in jointing the bus-bars by electric arc welding or pressure welding with a special tool (Fig. 282).

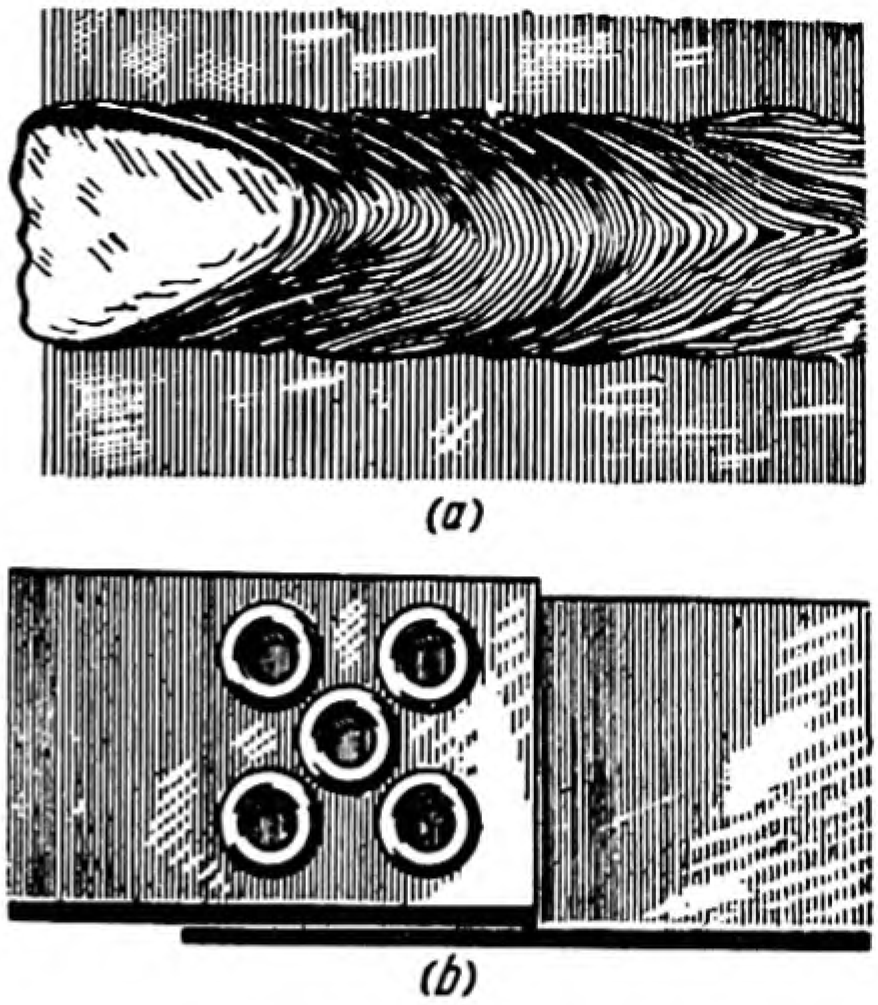


Fig. 282. Bus-bar joints:
a—electric arc-weld joint, *b*—pressure welded joint.

Bus-Bar Installation. Main buses, when of single-bus-bar design, have their bus-bars placed directly flat side down and secured on the caps of the post insulators (Fig. 283*a*). Main buses of multi-bus-bar design have their bus-bars fixed on the insulators with special clamps. Examples showing how bus-bar clamps are used to install the bars either flat or on-edge can be seen in Fig. 283*b* and *c*.

Tap-off bus-bar connections from the main bus-bars to units of apparatus and bus-bar connections between units of apparatus are usually made with the bus-bars "flat" mounted.

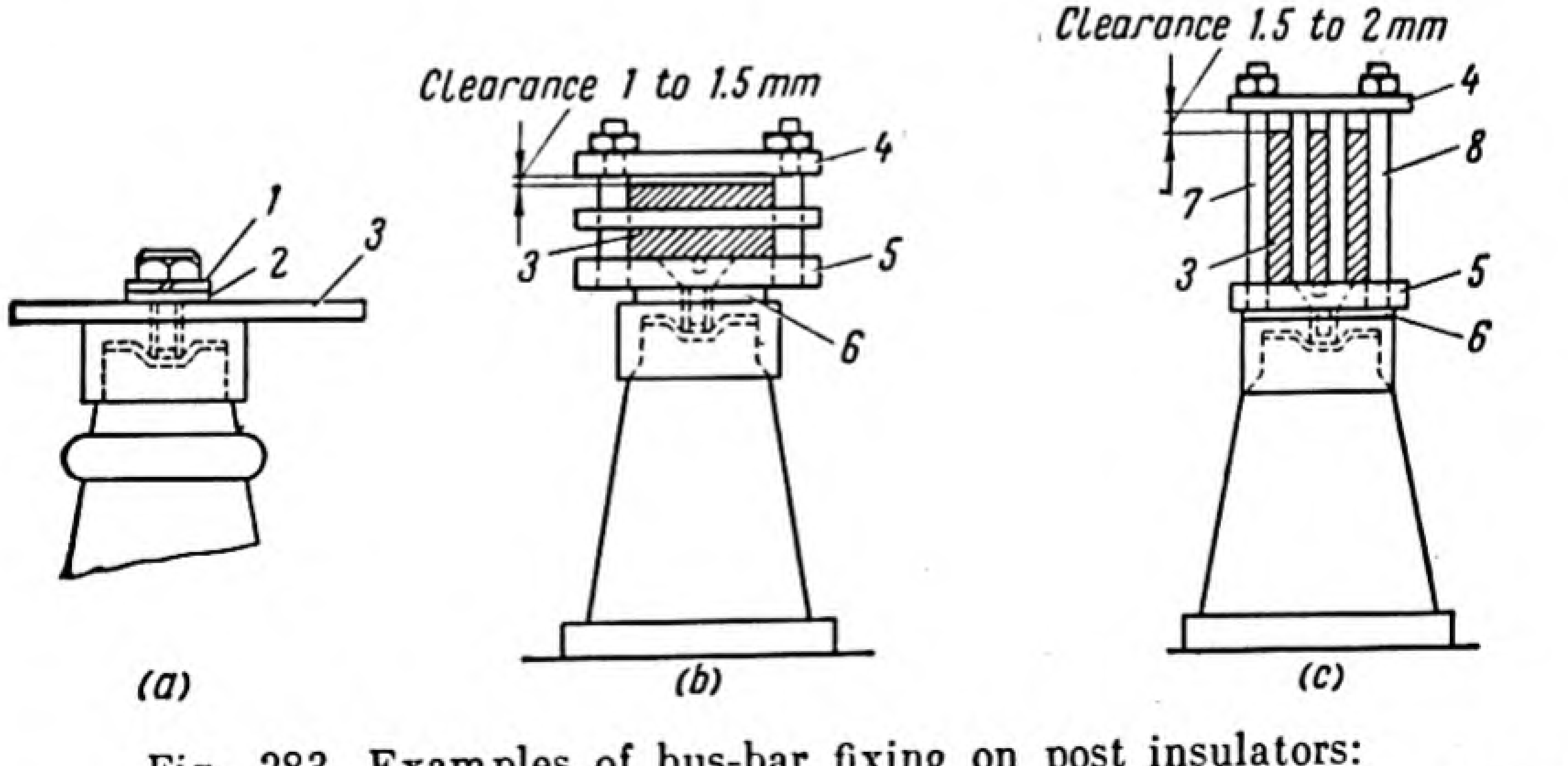


Fig. 283. Examples of bus-bar fixing on post insulators:
a—direct fixing to insulator cap fitting, *b*—flat fixing with bus-bar clamps, *c*—on-edge fixing with bus-bar clamps; *1*—spring washer, *2*—standard steel washer, *3*—bus-bar, *4*—upper clamping plate, *5*—lower clamping plate, *6*—pressboard pad, *7*—steel stud, *8*—brass stud.

Table 30

Operation-Sequence Card for Separate Main Operations of Bus-Bar Installation

Name of operation	Tools, mechanisms and appliances	Procedure
Sorting of bus-bars	Folding rule, tape measure, vernier caliper	Sort bus-bars according to cross-sectional area and length. Bundle each group of bus-bars and mark the switchgear section they are intended for on an attached tag or on one of the bus-bars. Also draw up a list of available and sorted bus-bars and of the lengths of bus-bars which require bending
Straightening of bus-bars	Straightening roller unit, levelling plate, screw press, winch, wooden mallet, 800-gram hammer, aluminium and wooden striking pads	A bus-bar requires straightening when it has a curvature greater than 2 mm per metre of length. The bus-bars must be straightened in a cold condition. On large sites with a large volume of work this is done on a straightening roller unit or a screw press. On small sites bus-bars are straightened by hand on a levelling plate or I-beam with a wooden mallet or hammer; in the latter case the striking is done through a cushioning pad. For copper bus-bars the pads may be of aluminium, for aluminium bus-bars — of aluminium or wood. Bus-bars of small cross-sectional area received in coils are straightened by stretching with a winch
Preparation of templates for bending and marking-off of bus-bars	Bench vise, 500 to 600-gram hammer	Make templates according to requirements of working drawing; use steel (hot-rolled) wire of 4 to 6 mm diameter. Bend template along a curve corresponding to the bus-bar axis. Measure the length of each template and cut bus-bars to these lengths

Table 30 continued

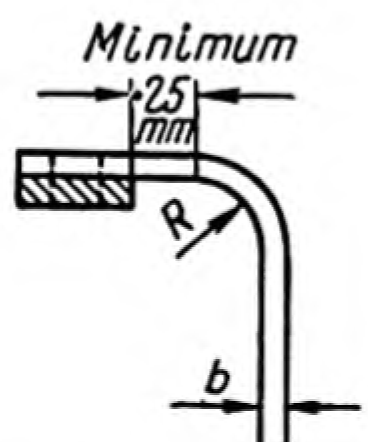
Name of operation	Tools, mechanisms and appliances	Procedure
Cutting of bus-bars	Hacksaw, disk saw, bastard files, model УПП (UPP) and ПН-1 (PN-1) press shears	Use hacksaw only in separate cases of minor amounts of work as it is very unproductive. A good method is to use press shears such as the УПП (UPP) and ПН-1 (PN-1) press shears, or a disk saw. The last method has the disadvantage of leaving burrs on the bus-bar ends which require filing
Bending of bus-bars	Bus-bar bender, appliance for making offset bends, appliance for making twist bends, portable forge	Bend bars to fit wire templates laid on the edge axis
(a) 		Bus-bars are bent: a) with flat bends

Table 30 continued

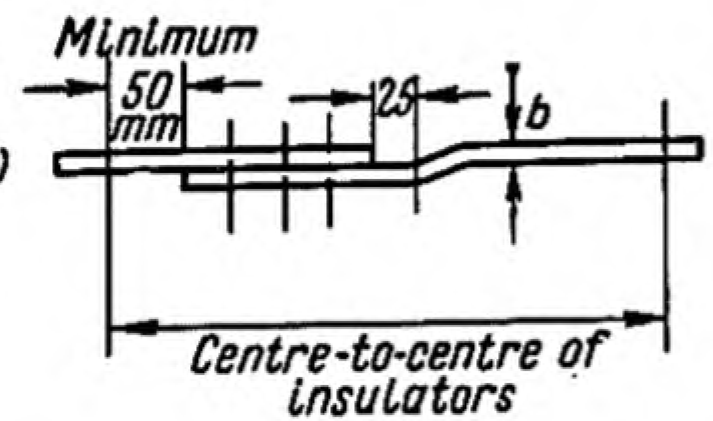
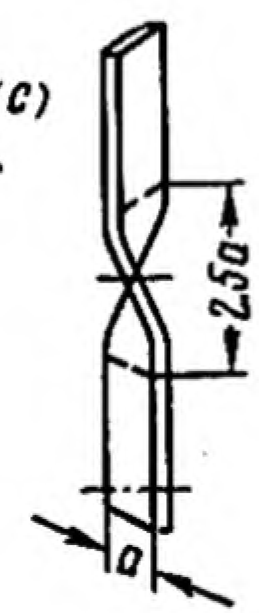
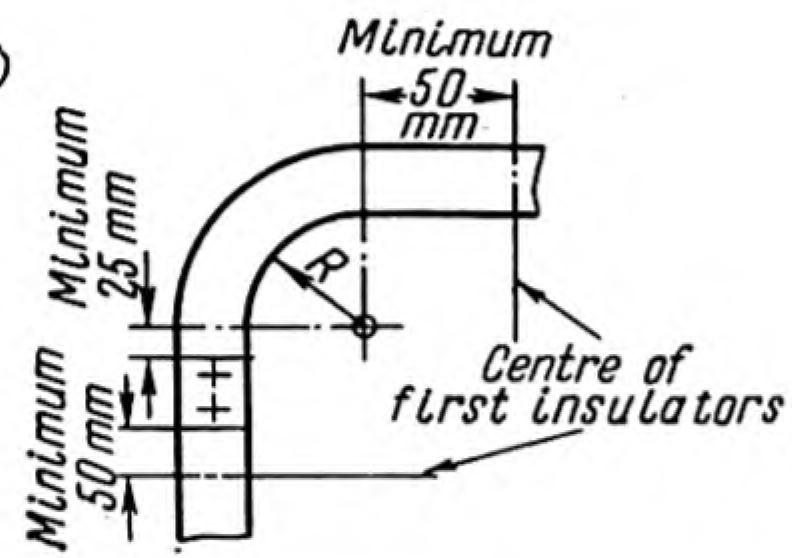
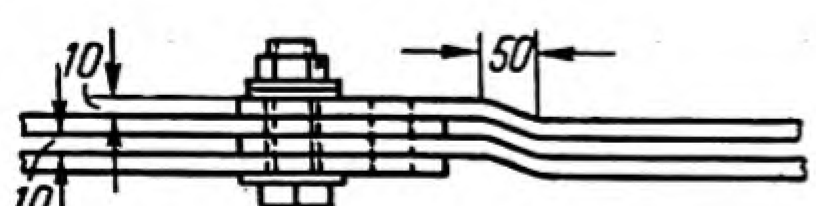
Name of operation	Tools, mechanisms and appliances	Procedure
(b) 		b) with offset bends
(c) 		c) with quarter-twist bends

Table 30 continued

<table>
<tr><th>Name of operation</th><th>Tools, mechanisms and appliances</th><th>Procedure</th></tr>
<tr><td>(d)
</td><td></td><td>d) with on-edge bends, copper bus-bars to be bent heated to 350°C, aluminium bus-bars to 250°C, steel bus-bars to 600°C.
Take minimum bending radii from the table below:
<table>
<tr><th rowspan="2">Bend</th><th rowspan="2">Bus-bar size, mm</th><th colspan="3">Minimum radius of bend (to inside edge), mm</th></tr>
<tr><th>Copper</th><th>Aluminium</th><th>Steel</th></tr>
<tr><td>Flat</td><td>Up to 50×5</td><td>2b</td><td>2b</td><td>2b</td></tr>
<tr><td></td><td>Up to 100×10</td><td>2b</td><td>2.5b</td><td>2b</td></tr>
<tr><td>On-edge</td><td>Up to 50×5</td><td>a</td><td>1.5a</td><td>0.5a</td></tr>
<tr><td></td><td>Up to 100×10</td><td>1.5a</td><td>2a</td><td>a</td></tr>
</table>
Note: a—bar width, b — bar thickness.</td></tr>
<tr><td>Bolt jointing of bus-bars:
a) by lap jointing
</td><td></td><td>Used to join main bus-bars in sizes up to 100×10 mm, and also to joint tee-off bus-bars to main buses at apparatus connections.

Make overlap equal to twice bus-bar width. To continue general axis of bus-bars and support insulators, offset bend bus-bars at the joints</td></tr>
</table>

Table 30 continued

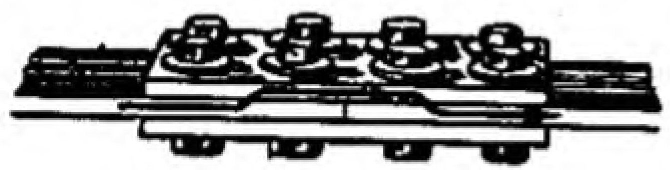
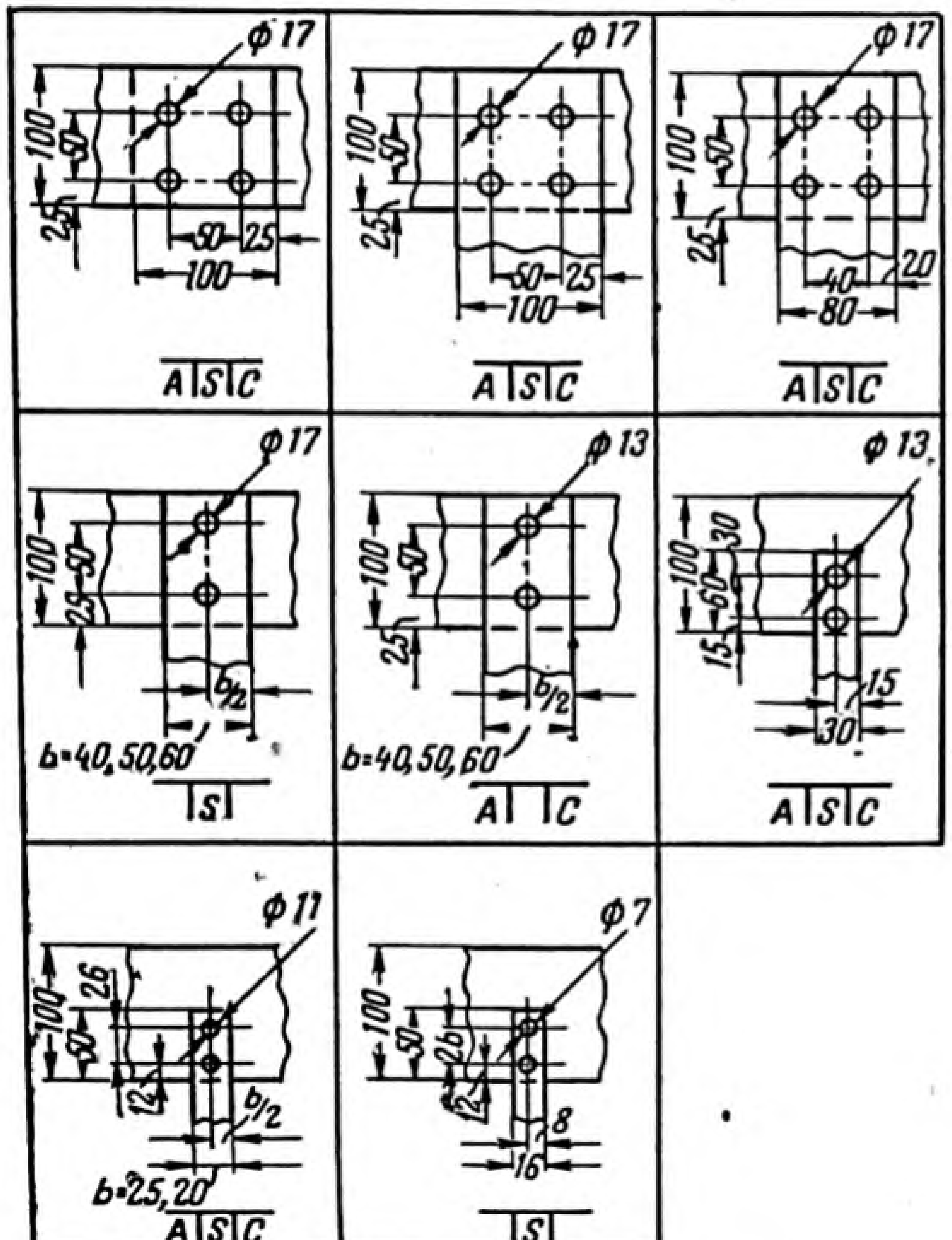
Name of operation	Tools, mechanisms and appliances	Procedure
b) by butt jointing with double cover plates 		Used only for main bus-bars. Place spacer plates between bus-bars of multi-bar main buses. Always use two cover plates, use spacer plates one less in number than bus-bars. Make both cover and spacer plate length equal to twice bus-bar width
Preparation of bus-bars for bolted-contact jointing:		
a) lay-out and marking-off of holes for main bus-bar jointing	Steel rule, back square, scriber, centre punch	Before marking off for main bus-bar joints make sure that joint or tap-off bus-bar connection will not coincide with position of a support insulator
b) punching or drilling of holes in bus-bars	УПП (UPP) and ПН-I (PN-1) presses, drilling machines, electric hand drills	Examples of typical layouts for bolt-jointed bus-bar connections can be seen in the insert below. Use electric hand drills when amount of work is small or bent bus-bar is difficult to place on a machine tool

Table 30 continued

Name of operation	Tools, mechanisms and appliances	Procedure



Use the following table for selecting bolt-hole diameter according to given bolt size:

Diameter, mm		Diameter, mm	
Bolt	Hole	Bolt	Hole
6	7	13	15
8	9	14	16
9	10.5	15	17
10	11.5	16	18
12	13.5	18	20

Note: Letters *A*, *S* and *C* in the insert indicate the bus-bar materials: aluminium, steel and copper, respectively.

Table 30 continued

Name of operation	Tools, mechanisms and appliances	Procedure
c) preparation of contact surfaces	Vises, bastard files, bus-bar milling machine, wire-brushing machine	Do hand filing only when amount of work is small. When bus-bars are without large defects, clean their contact surfaces on a wire-brushing machine. Operations for aluminium bus-bar contact surface preparation are: 1) rough finishing (file, bus-bar milling machine, wire-brushing machine); 2) cleaning with steel brush through layer of petroleum jelly; 3) removal of metal cuttings and petroleum jelly, and recoating with fresh petroleum jelly; 4) second cleaning with steel brush through petroleum jelly coating without removal of coating directly prior to assembly of joint. Bear in mind that the surface finishing must not reduce bus-bar thickness at the joint by more than 1 to 2 per cent
d) tinning of copper and steel bus-bar contact surfaces	Solder-melting ladle, soldering torch or heating forge	Tin copper bus-bars for jointing only for outdoor installation or installation in premises with atmospheres containing moisture, active gases, or with temperatures greater than 60°C. Tin steel bus-bar contact surfaces in all cases. Use ПОС-30 (POS-30) tin-lead solder, in specially vital cases use ПОС-90 (POS-90) solder; do the soldering with a rosin flux or special soldering paste. Tin by pouring the solder over the necessary surface

Table 30 continued

Name of operation	Tools, mechanisms and appliances	Procedure
e) applying of anti-corrosion coating		After surface finishing operations have been completed on copper and steel bus-bars, coat surfaces with petroleum jelly and tie a paper wrapping over them. Before making up joint, wash old coat off with petrol and apply fresh thin coating.
f) bolting-up	Socket wrench for given size of bolt, with torque control	Bolt up contact joint by placing a steel spring washer under the nut on each bolt. This gives bus-bars possibility of free expansion during their temperature rises, prevents self-loosening of nuts, and prevents denting both under nut and bolt head. Tighten the bolts with the appropriate wrench turned only by hand

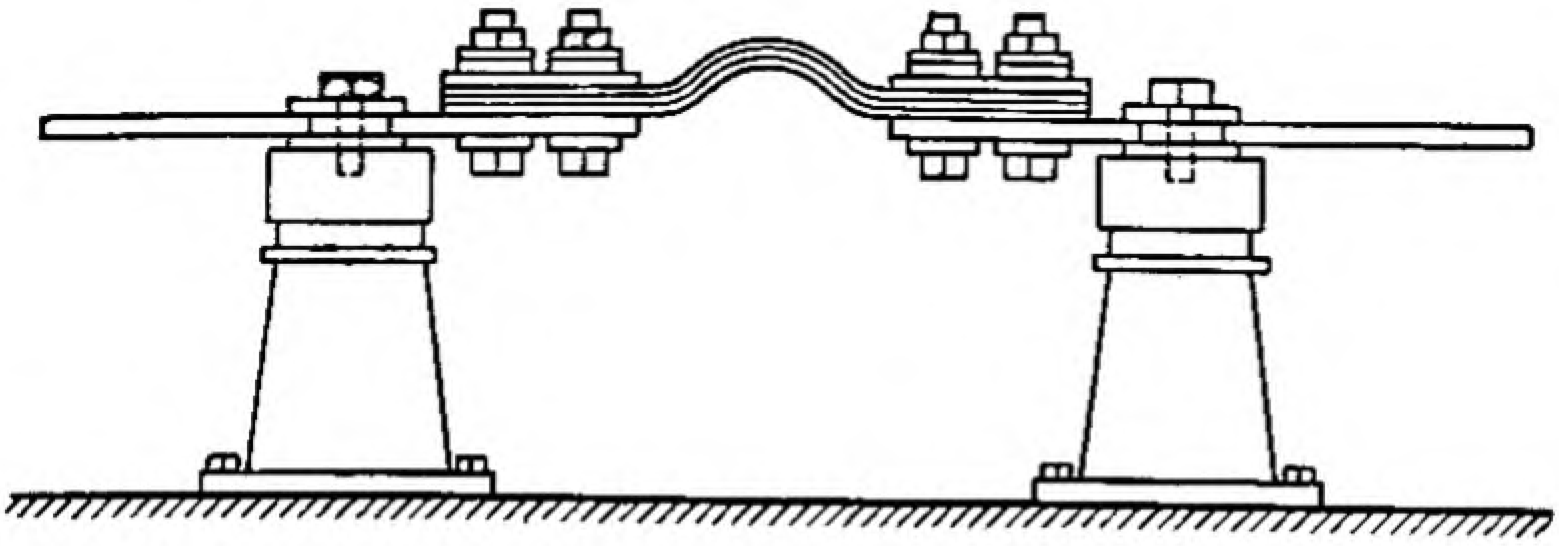


Fig. 284. Bus-bar expansion compensator.

When bus-bars are installed, measures are taken to provide for possible elongation during temperature rise due to the heating effect of the load current or a short-circuit current. Clearances of 1 to 2 mm are left in the bus-bar clamp assemblies for this purpose.

Holes for the fixing bolts in bus-bars which are to be laid directly on the post insulator cap fittings should be of oval shape, both at the intermediate spans and at the ends. Spring washers are placed under the heads of the bolts. Bus-bars installed for runs over 15 to 20 metres long should have bus-bar expansion compensators interposed in them (Fig. 284). If provision is not made for bus-bar expansion, this may result in breakage of the bus-bar assembly when the temperature of the bus-bars rises.

In securing a bus-bar laid flat on an insulator cap fitting, the length of the fixing bolt must be selected so that its end will not press down against the porcelain head of the insulator. Otherwise, the cap fitting will be torn away from the cementing layer or cracks will appear in the cementing compound when the bolt is screwed in.

The connection of bus-bars to apparatus terminals is illustrated in Fig. 285.

Monitoring Current-Carrying Parts for Overheating. Within indoor switchgear installations monitoring of contact overheating is mainly accomplished with

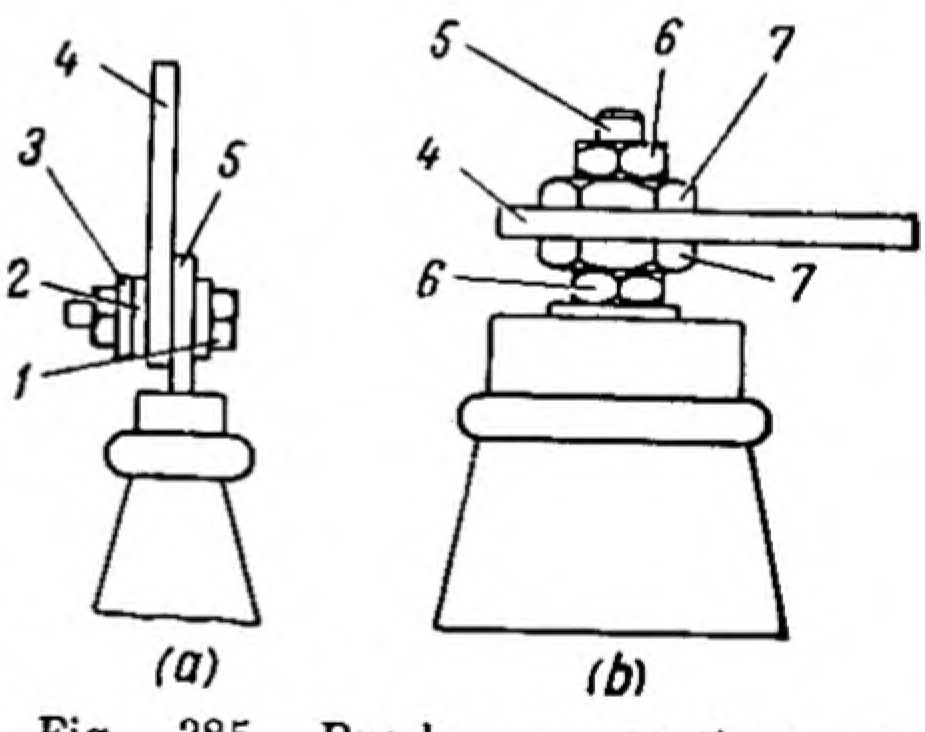


Fig. 285. Bus-bar connections at apparatus terminals:

a—through bolt connection, *b*—stud-nut connection; *1*— steel bolt, *2*— standard washer, *3*—spring washer, *4*—bus-bar, *5*—contact end of apparatus terminal, *6*—standard brass nut, *7*—low brass nut.

thermofilms which are bonded to the bus-bars with varnish at the bolt-jointed contact connections. Such films change colour on rise in temperature.

Table 31

Thermofilm Indicator Characteristics

Normal colour of thermofilm at temperatures up to 35°C	Thermofilm colour corresponding to temperature attained by current-carrying parts	
	First colour change	Second colour change
Yellow (bright)	Orange at 44° to 50°C	Red at 90° to 100°C
Green	Brown at 50° to 60°C	Dark red at 90° to 100°C
Red	Dark cherry colour at 60° to 70°C	Black at 100° to 110°C

The characteristics of the above thermofilm indicators can be seen in Table 31.

Thermofilms cut into circular pieces may also be bonded to the heads of the bolts.

To bond thermofilm to a given surface, the latter must be thoroughly cleaned and wiped off with a cloth dipped in petrol. A coating of benzyl cellulose varnish is then applied to the cleaned surface and the thermofilm laid on it. Following this, a new coating of the varnish is applied over the thermofilm.

3. Requirements of Prefabricated Cell Switchgear, Metalclad Cubicle Switchgear and Unit Transformer Substation Installation

KCO (KSO) prefabricated cell and KPY (KRU) factory-assembled metalclad cubicle equipment is installed in the switchgear rooms after the ceilings and walls have received their finish coatings and have been lime washed. Only the floors are left unfinished because they may be damaged when the cells or cubicles are moved over them during installation.

When the cells or cubicles of such installations are put in place on previously grouted-in steel channels, the latter should be checked for true horizontality.

The cells or cubicles are moved directly up and onto their built-in channel base by lifting mechanisms or on rollers. When cubicles with withdrawable trucks are to be installed, the trucks are first rolled out. The cubicles can then be mounted with greater ease where required by the assembly drawing.

The cells or cubicles should be set close to each other and fitted so that their frontal panels form one general plane. After this, they may be jointed together with M10 bolts inserted into the holes provided for this purpose in the sidewall frames.

Cells or cubicles are joined correctly if the locating holes provided in the front part of the sidewall frames fully match

with each other. Next checked and adjusted (when installing withdrawable truck equipment) is proper travel of the trucks into and out of their cubicles.

When this work is completed, the footing frame of each cell or cubicle is bolted to the built-in base channels.

After mounting of the cells and cubicles has been completed, the main bus-bars are put in, care being taken to see that the numbers marked on the bus-bar sections coincide with the numbers of the cells or cubicles.

To the main bus-bars are next attached the tee-off bus-bars, following which the secondary circuit bus-bars are installed.

For earthing, the underframe part of each cell or cubicle in the installation is tack welded securely to the built-in base channels. In addition to this, the channels are butt welded to each other, and the bases are joined to the main earthing bus-bar by not less than two welded connections made of 40×4 mm strip steel.

Unit-type transformer substations such as the КТП (KTP) class are installed practically in the same way as the above switchgear installations.

4. Fundamental Features of Secondary (Ancillary) Circuit Installation

Secondary circuit wiring (small wiring), on panels, is generally installed by direct fixing to the metallic surfaces of the various control and relay panels, either on the face or the back sides. The wiring is laid out upon an insulating underlayer of varnished cloth or electrical pressboard preliminarily bonded to the surface. Runs of such wiring are fixed by means of clamping straps (Fig. 286*a*) secured with screws driven into holes drilled and threaded in the panels. Usual strap spacings range from 150 to 175 mm. To protect the wires, a padding strip, usually of electrical pressboard, is provided between the wires and the clamping strap.

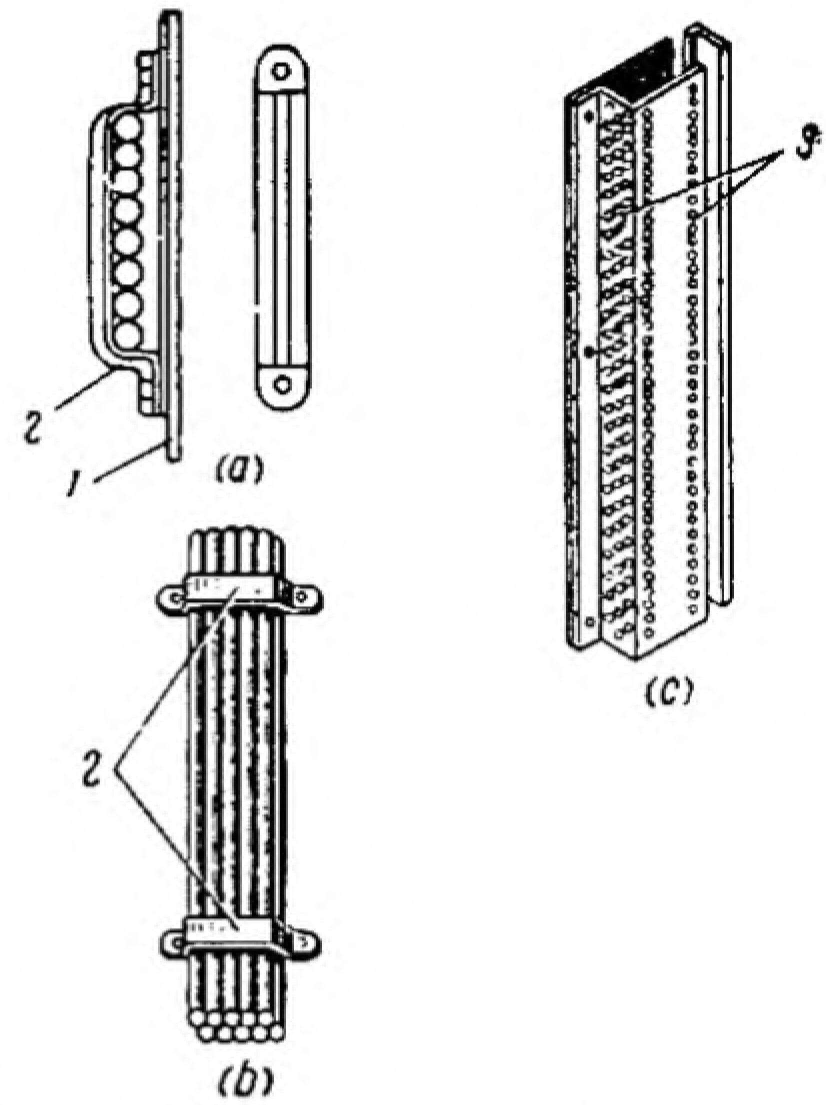


Fig. 286. Methods of installing secondary (ancillary) wiring:
a—by strap clamping to switchboard panel surface, *b*—in "bunched-air-runs", *c*—in perforated raceway; *1*—insulating underlayer, *2*—insulating padding strip, *3*—holes for lead-out of wires.

A method widely used in secondary circuit installation is what can be called "bunched-air-run" wiring which takes the

form of wires strapped into bunches (Fig. 286*b*) run in air and fixed to the panels only at two or three points in a run.

A modern method of installing switchboard and control-panel wiring is to run the wires loosely bunched in perforated sheet metal raceways (Fig. 286*c*).

By the above method the wires are run unsecured in the raceways, being bunched only by bandings of cotton or p.v.c. tape. Any wire, through an insulating bushing inserted in one of the raceway perforations, can be brought out for practically direct connection to the terminal of a device where most convenient.

The external secondary wiring used to interconnect the various control panels and control devices takes the form of rubber- or paper-insulated control cable circuits.

Control cables are installed in the same way as power- and lighting-circuit cables.

5. *Elements of Protective Earthing Installation*

As was stated earlier, when any metallic parts of an electrical installation or any of its equipment, due to a breakdown in the insulation, are liable to acquire an electrical potential, all such parts and equipment must be connected to an earthing circuit.

Protective earthing circuit installation can be divided into two main elements: the installation of the outdoor earthing electrodes and their buried bus parts, and the installation of the indoor earthing bus-bar system.

Outdoor Earthing-Electrode Circuit Installation. At first trenches are laid out and dug as required by the working drawings, the laying-out being done by the electricians, the digging by a separate team.

Trenches must be dug from 0.6 to 0.7 metre deep with their centres not closer than 2 to 2.5 metres to the walls of buildings.

The earthing electrodes are prepared while the trenches are being dug (if they have not been sent ready-made to the site from a workshop). Steel pipes 2″ to $2^1/_2$″ in size and from 2.5 to 3 metres long may serve as earthing electrodes. A distance of 2.5 to 3 metres should be observed between the electrodes. Similar lengths of angle iron are also used today as earthing electrodes.

The earthing electrodes may be driven into the soil with a manual driving appliance such as the Martynov-Brodyansky hand driver (Fig. 287) or with a special vibratory power driver (Fig. 288) suspended from a crane. Whether of pipe or angle iron, the electrodes are driven into the soil until only 150 to 200 mm are left remaining above the bottom surface of the earth trench. The interconnecting earthing strip steel can then be arc-welded to the protruding ends of the earthing electrodes.

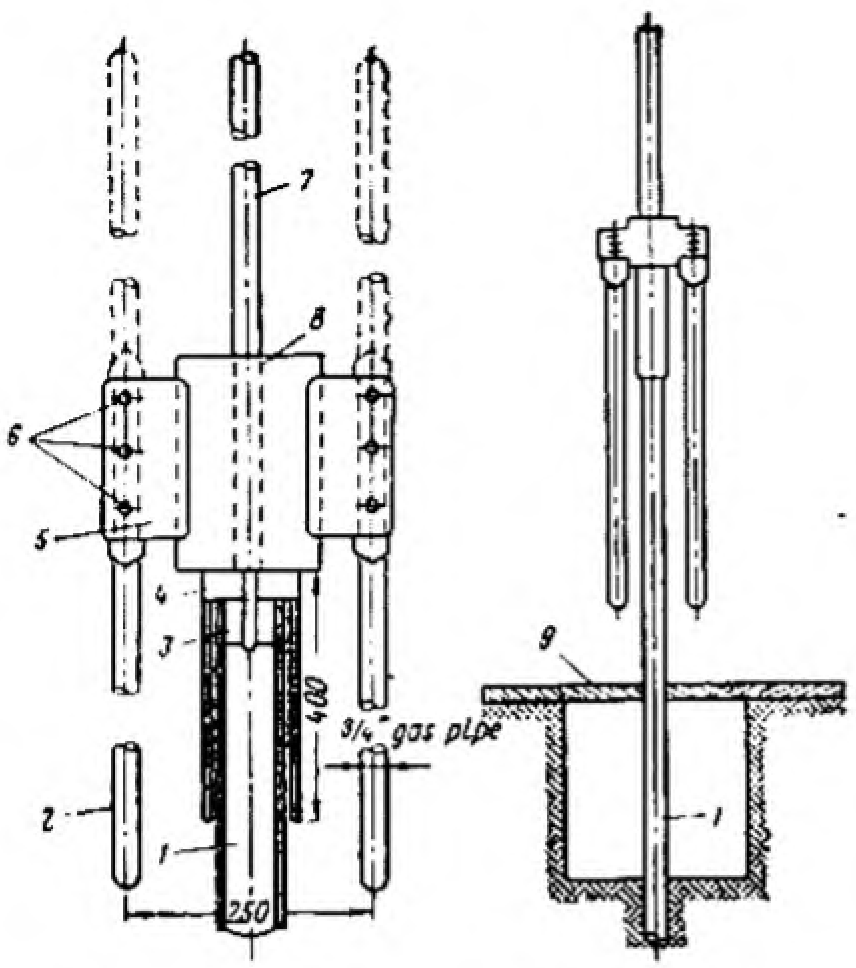


Fig. 287. Martynov-Brodyansky earthing-electrode manual driving appliance:

1—pipe earthing electrode, 2—handle, 3—ring, 4—striking headpiece, 5—handle-securing plates, 6—fixing screws, 7—guide rod, 8—ram, 9—footboard.

The earthing strip steel is usually of 40×4 mm size. It is more or less straightened, laid in the trench on-edge, and is arc-welded to the driven-in electrodes after being first temporarily secured to them by arc-welded straps (Fig. 289). To check that the earthing strip steel is solidly welded to the earthing electrodes, the joints are struck with a 2-kg sledge hammer.

Where an earthing strip steel connection is run into a building, an entrance sleeve cut from steel pipe is cemented into the wall.

After an outdoor earthing circuit has been completed, its "as-installed" dimensions, obtained by measuring off its distances from surrounding permanent structures, must be re-

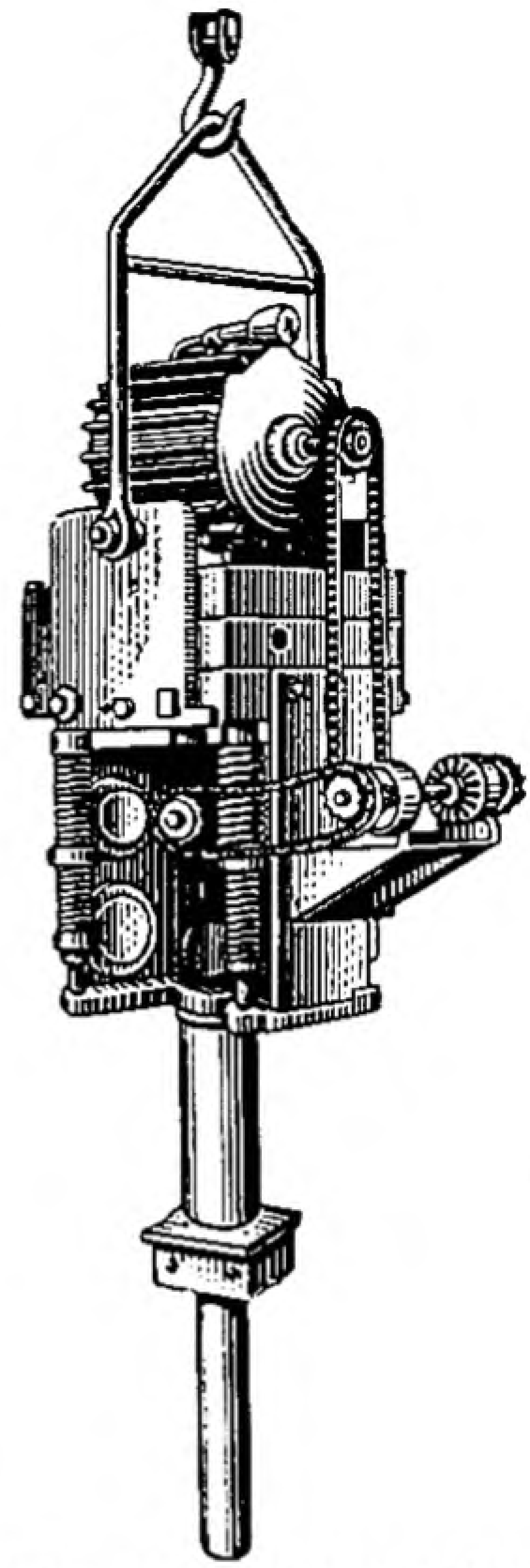


Fig. 288. Electric vibratory earthing-electrode driver.

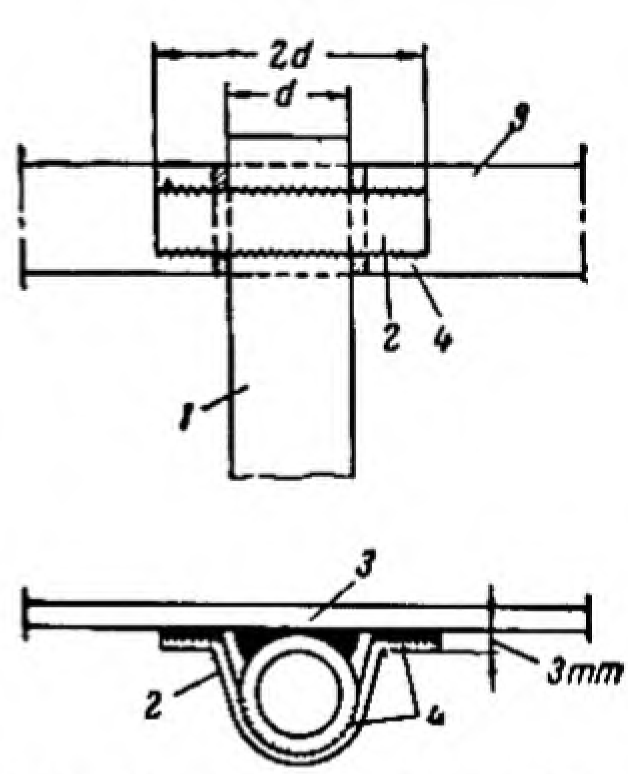


Fig. 289. Connection of earthing strip steel to a pipe earthing electrode:
1—pipe electrode, 2—strap, 3—earthing strip, 4—arc-weld seam.

corded on "as-installed" plans. Following this, the trenches are backfilled with soil. The backfilling must be tamped in.

Installation of Lines of Indoor Earthing Bus-Bars. Within buildings the earthing bus-bars are installed on wall and ceiling surfaces by means of cemented-in anchors of various shape, depending upon the place and conditions of fixing.

It is wide practice to fix earthing bus-bars with a type СМП-1 (SMP-1) powder-actuated stud driver (Fig. 290).

When earthing bus-bars are installed within buildings, the spacings between fixings given in the table below should be observed.

Earthing strip size, mm	Distance between fixings, mm
20×3	1,000
30×4	850
40×4	800
50×5	—
60×6	650
80×6	650
100×6	650

Where the earthing bus-bars must pass across temperature-expansion joints in a structure, an expansion loop must be provided. At wall through holes the bus-bars should be protected by steel-pipe sleeves cemented into the holes.

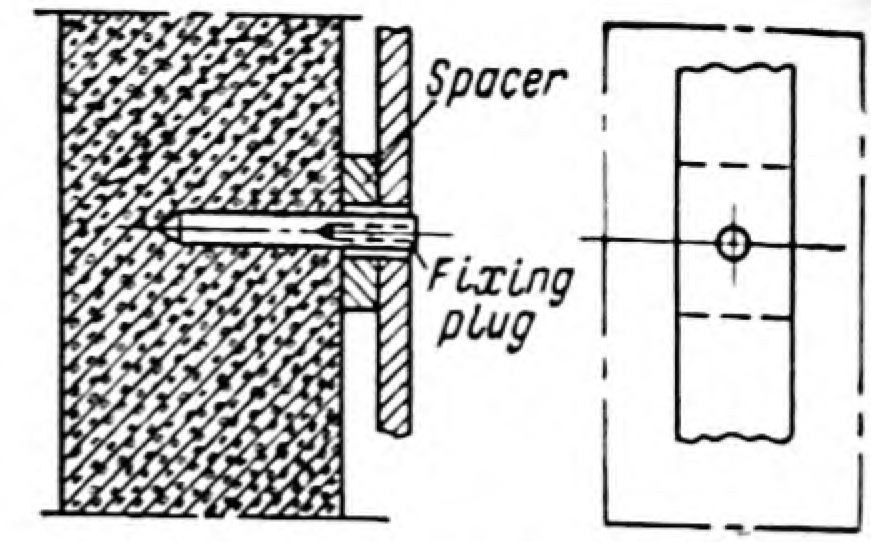


Fig. 290. Earthing bus-bar fixing inside buildings driven with powder-actuated stud driver type СМП-1 (SMP-1).

Earthing main bus-bar jointing and tap-off connection is done by arc welding. Earthing connections at the various units of apparatus are made with the aid of the earthing bolts always provided on each piece of apparatus or each switchgear component.

If apparatus is mounted on metalwork supports, the earthing bus-bar connections are arc-welded directly to the support metalwork. To ensure adequate electrical contact, the support surfaces of the apparatus and the mating bearing surfaces of the support metalwork must be thoroughly cleaned and coated with petroleum jelly or a neutral grease.

When the installation of an earthing bus-bar system within a building has been fully completed, it is given a coating of black asphalt varnish. The places allotted for connecting temporary safety-earthing-conductor sets should be left unvarnished.

Part Five

POWER ELECTRICAL EQUIPMENT

Chapter X

TYPES AND FORMS OF ELECTRIC MOTORS AND THEIR MANUAL CONTROL

1. General

Electric motors which are installed in industrial works operate under a very wide range of conditions. This is why they are of various design.

Thus, when the surrounding conditions in which the motor is placed are quite favourable, the motor does not have to be designed with any special means of protection and is therefore what is called an *open* motor (Fig. 291*a*).

In many cases motors require protection from ingress of foreign objects. To meet such conditions they are provided with protective enclosures and

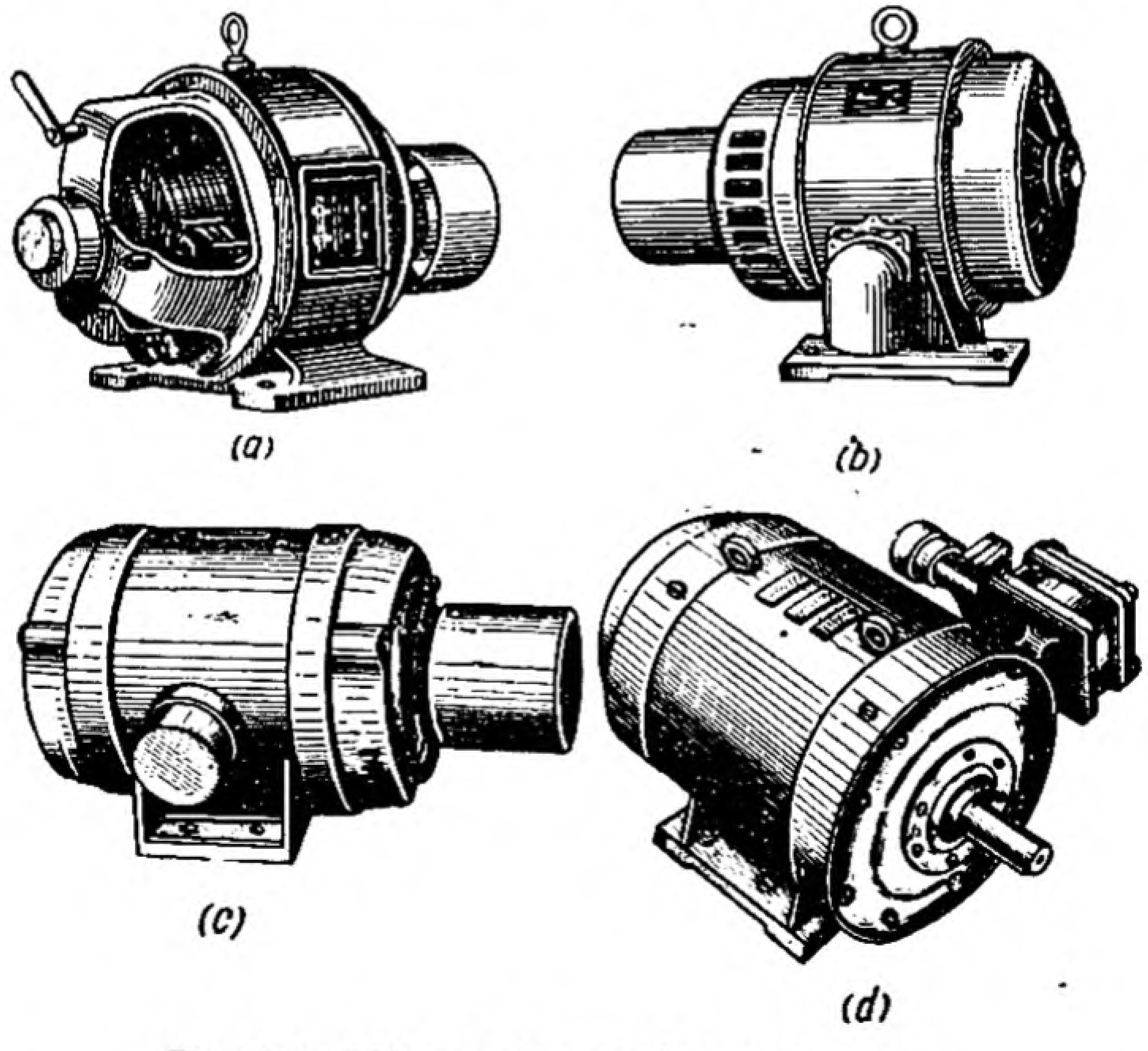


Fig. 291. Different forms of electric motors:
a — open motor, *b* — protected motor, *c* — dripproof motor, *d* — flameproof motor.

are called *protected* motors (Fig. 291*b*).

Electric motors protected against the penetration of vertically falling drops of water are called *dripproof* motors (Fig. 291*c*). When protected against liquids falling at an angle of 45 degrees to the vertical, they are called *hoseproof* or *splash-proof* motors.

Motors of special design are also available, for example: flameproof (Fig. 291*d*), dustproof, built-in, flanged, etc.

As to kind of power supply, electric motors are designed to operate with d-c or a-c supply.

Among the main characteristics by which electric motors are rated are: power capacity in kilowatts (kw), voltage in volts (v), rated load current in amperes (a), speed of rotation in rpm, and power factor ($\cos \varphi$).

The above data, as a rule, are given on the rating plate of the electric motor.

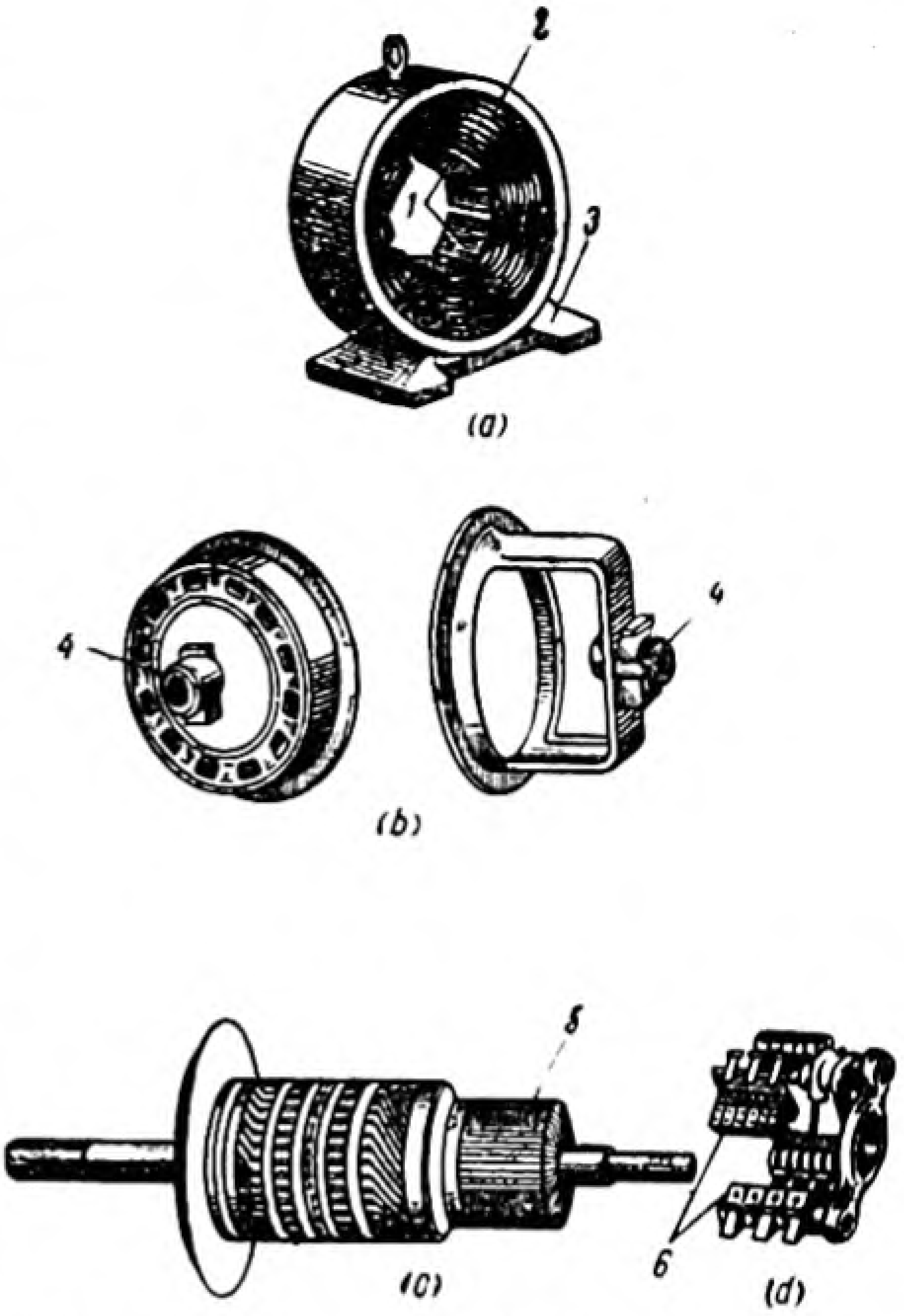


Fig. 292. D-c electric motor and its main parts:

a—frame yoke), *b*—bearing end shields, *c*—armature, *d*—brush rigging; *1*—pole core, *2*—pole coil, *3*—frame, *4*—bearing, *5*—commutator, *6*—brushes.

2. *Main Parts of D-C Electric Motors*

A d-c electric motor consists of two main parts:

1) the stationary frame (yoke), designed mainly for creating the magnetic field;

2) the rotating armature.

The frame (yoke), in d-c motors sometimes called the inductor, consists of the magnetic yoke proper and the poles (Fig. 292*a*). Each pole has a core assembled of electrical sheet steel laminations 0.5 to 1.0 mm thick and carries a pole coil through which field current is passed.

Low- and medium-power electric motors have end-shields (Fig. 292*b*) which are secured directly to the frame and accommodate the motor bearings.

Electric motors of high power rating generally have pedestal bearings arranged separately from the frame and secured to the motor bedplate.

The bearings in motors may be of two types: sleeve (oil-ring lubricated) or antifriction (ball bearing and roller bearing).

Sleeve bearings, as renewable parts, may have removable half-

shells or integral bushes. Anti-friction bearings are replaced entirely.

The armature (Fig. 292*c*) comprises a core assembled of 0.5-mm sheet steel laminations. To decrease the appearance of eddy currents, the laminations are insulated from one another by a layer of thin paper, varnish or a thin layer of oxide formed on the surface of the lamination.

Thoroughly insulated, the armature winding is laid in the core slots and reliably secured. The leads from this winding are connected to a commutator also provided on the armature.

The commutator consists of a set of separate copper bars insulated from each other by mica. Connection of the armature to an external circuit is attained by means of brush rigging (Fig. 292*d*), in which carbon, graphite or copper-graphite brushes are carried by a set of brush holders.

Between the armature and the field poles there is an air space termed the air gap. Electric motors of low power rating have air gaps of 0.5 to 3 mm. In motors of high power rating the air gaps range from 10 to 12 mm.

3. Main Parts of A-C Three-Phase Asynchronous (Induction) Motors

The main characteristic of the asynchronous (induction) motor is that its speed, though determined by the given a-c supply frequency, is dependent upon the load carried by the motor.

Asynchronous (induction) motors have found wide application in industry because of their simple design, low cost, high efficiency and full reliability in service. But asynchronous motors also have certain shortcomings: difficulty of attaining wide speed control and drawing of large starting currents several times greater than the rated current.

Asynchronous three-phase motors are of two kinds:

1) slip-ring or wound-rotor;

2) squirrel-cage, an induction motor which has a short-circuited cage rotor winding.

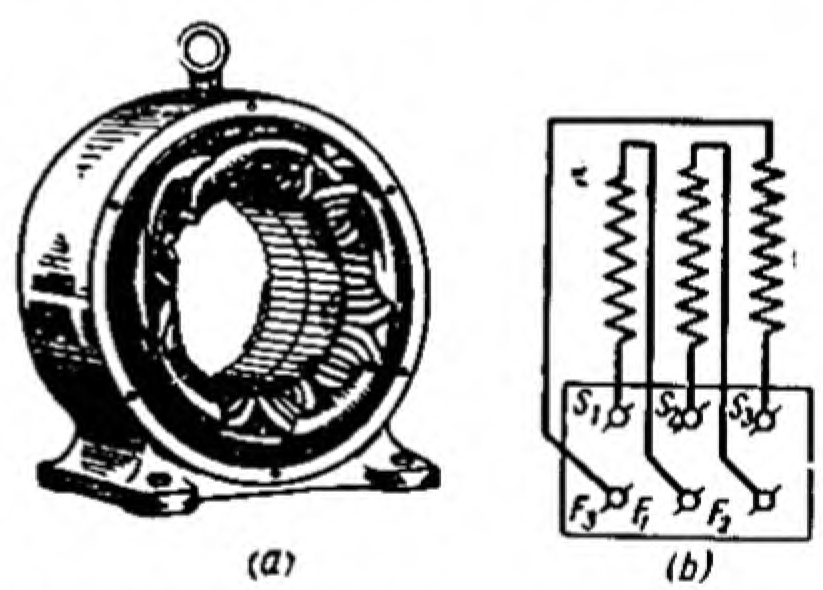


Fig. 293. Induction motor stator and connection of windings to terminal panel:

a—stator, *b*—connections of phase winding on terminal board.

The stationary part of a slip-ring motor is the *stator* (Fig. 293*a*). Pressed into the stator frame is a core stack assembled of laminations stamped from 0.5-mm electrical sheet steel. The laminations are made with openings so as to form the slots for the stator winding. To lower the eddy currents, the lamina-

tions are insulated from one another in the same way as the cores of d-c machines.

The start and finish of each phase winding consisting of a group of series-connected coil sections belonging to any given phase are brought out to the motor terminal board (Fig. 293*b*). The latter carries six terminals, two per phase. By interconnecting the terminals on the board, the motor winding can be either star- (Fig. 294*a*) or delta-connected (Fig. 294*b*).

The *rotor* (Fig. 295) is assembled in the same way as a d-c machine armature and its core consists of a stack of steel laminations insulated from one another.

The slots of the rotor in this case carry a three-phase winding connected to three slip rings on which a set of brushes ride. By means of these brushes the motor rotor is connected to a starting rheostat.

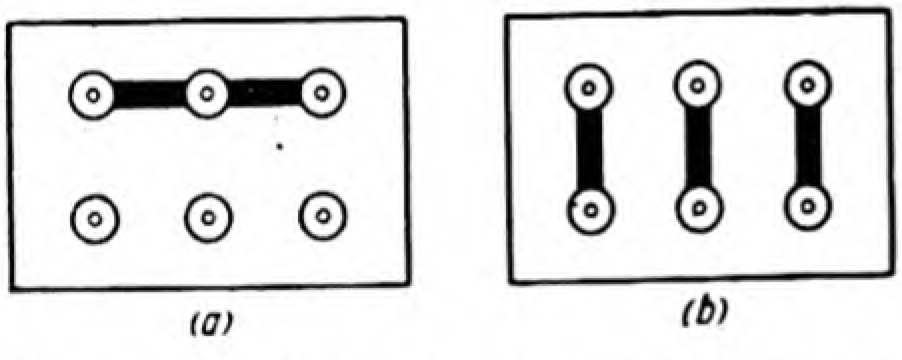


Fig. 294. Methods of connecting motors on their terminal boards:
a—star connection, *b*—delta connection.

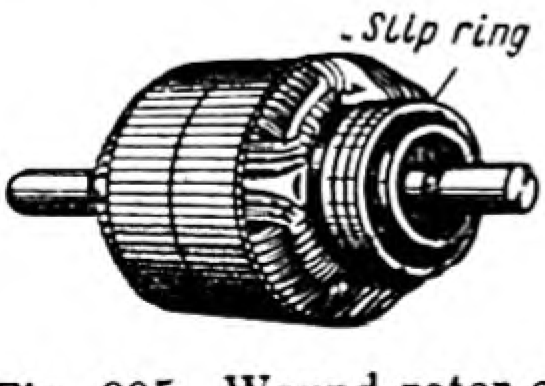


Fig. 295. Wound rotor of a slip-ring induction motor.

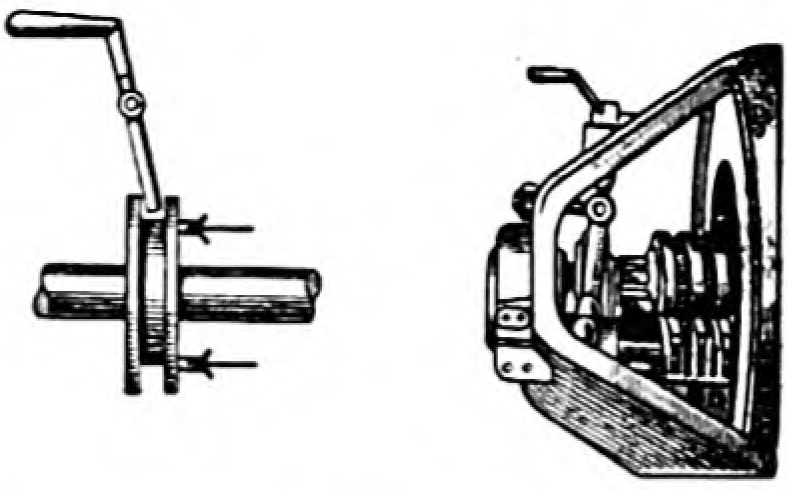


Fig. 296. Rotor-winding shorting and brush-lifting mechanism.

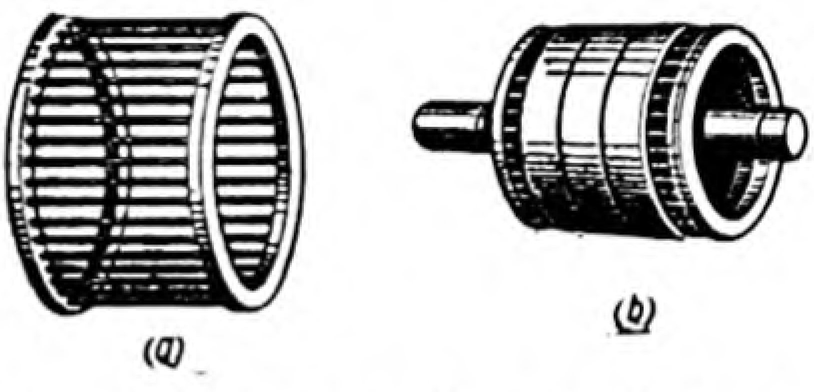


Fig. 297. Rotor of a squirrel-cage induction motor:
a—winding (squirrel cage), *b*—general view.

An arrangement also incorporated in such motors serves to short circuit the rotor winding and raise the brushes after the rotor winding is shorted. It is fitted on the shaft and controlled outside the motor (Fig. 296).

In a squirrel-cage induction motor the rotor has a winding made in the form of a cylindrical cage consisting of copper bars arranged parallel to the axis of the rotor. At their ends the bars are fitted and brazed into copper end rings (Fig. 297*a*). Rotor windings of such construction are called squirrel cages.

For strengthening the magnetic field and giving it the right direction into the stator, and also to reduce eddy currents (Fig. 297*b*), the squirrel cage

is arranged in a cylindrical core assembled of electrical sheet steel laminations.

In another form of construction of these motors, the rotor slots are filled with aluminium cast in to form an integral aluminium squirrel cage.

4. Electric Motor Manual Control Schemes

Control of Shunt-Wound D-C Motors. As is known, if a d-c motor is directly switched to supply, its starting current will rise to a value many times greater than its rated load current. This can lead to a number of highly undesirable aftereffects, in particular, to heavy sparking at the brushes or even to flash-over round the commutator, and also to the damage of drive parts coupled to the motor due

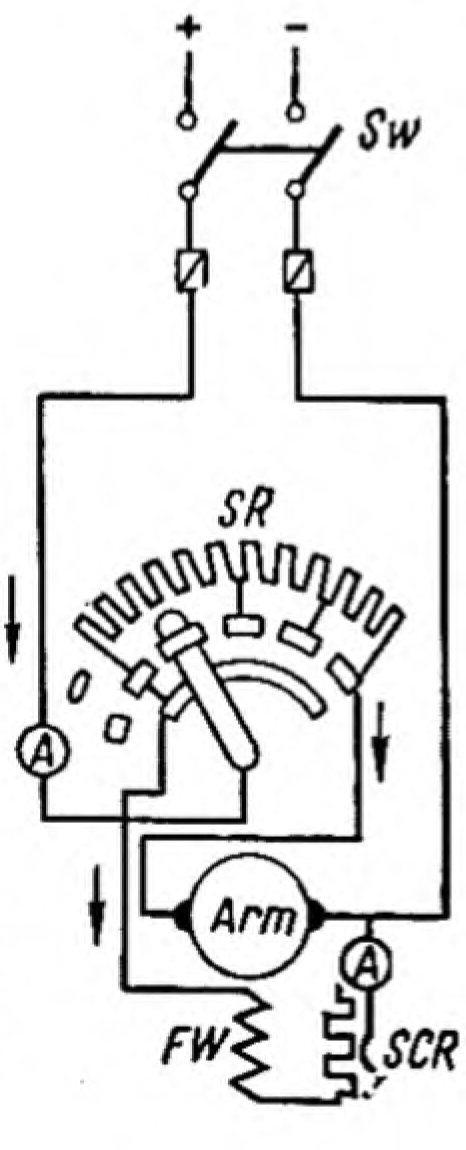


Fig. 298. Shunt-wound d-c motor starting and control circuit: *Arm* — armature, *FW* — exciting (field) winding, *SCR* — speed-control rheostat, *Sw*— switch, *A*—ammeter, *SR* — starting rheostat.

to the development of excessive torque, etc.

Furthermore, the high current which appears causes fluctuation in supply voltage and, naturally, affects normal operation of other electric motors connected to the same circuit.

Direct-on-line starting of such motor is therefore, as a rule, never practised. To limit the inrush of starting current, low and medium capacity d-c motors are switched in by special starting rheostats.

It also happens that the speed of rotation of a mechanism coupled to a motor must be changed from time to time. This is accomplished by a speed control rheostat.

The speed control rheostat is connected in the field (excitation) circuit of the motor. The principle upon which the rheostat operates consists in that the change in resistance within the field winding changes the value of the excitation current and, consequently, the strength of the flux in the field poles.

When more resistance is cut in with the rheostat, both the excitation current and the magnetic flux decrease. This increases the speed of the motor armature.

Fig. 298 shows a simplified control circuit for a shunt-wound d-c motor.

Before the motor is started, the starting-rheostat control lever must be set on idle contact *O*. To aid motor starting, the speed control resistance must be fully cut out. The excitation current, magnetic field and torque will then reach full value.

After switch *Sw* is closed for connection to supply, the starting-rheostat control lever is notched over to the first contact position. Then, as the motor begins to gain speed, the control lever is notched over to the second contact position. This cuts out part of the starting resistance. The start is completed when the control handle is finally notched step by step over into the last running-contact position.

When the motor must be stopped, the starting rheostat control lever is turned back to the idle-contact position. In this position the field winding is short circuited across the starting rheostat resistance and the motor armature. Such connection of the winding safeguards the motor against the possibility of arcing due to current interruption and against appearance of overvoltages which can puncture the field coil insulation.

A thing to remember during starting and stopping of a motor is that the starting rheostat resistance elements are designed only for short-time passage of current through them. Therefore, the rheostat control lever must never be allowed to remain on an intermediate contact position; this will result in burn-out of the resistance elements.

The speed control rheostat in the field circuit must have no idle contacts or produce any interruptions in the excitation circuit; if the field circuit is broken or opened, a current of such large magnitude can flow through the armature that the motor will be damaged.

Another danger is that a break in the field winding circuit results in a very sharp rise in speed of rotation of the armature. The motor may "run away" iu such cases.

Control of Series-Wound D-C Motors (Fig. 299). Series motors are started in practically the same way as shunt-wound motors. A series-wound motor must never be switched on without load, as it can gain such a high speed that the armature bandings will be ruptured and the windings damaged.

Another characteristic of this motor is that it has to be constantly kept under load as any sudden loss in load will cause it to overspeed and "run away".

Because of the above characteristic, series-wound motors are very frequently provided with overspeed devices to automatically shut them down after a certain speed limit is reached. In other cases they are solidly connected to their loads, the minimum load being great

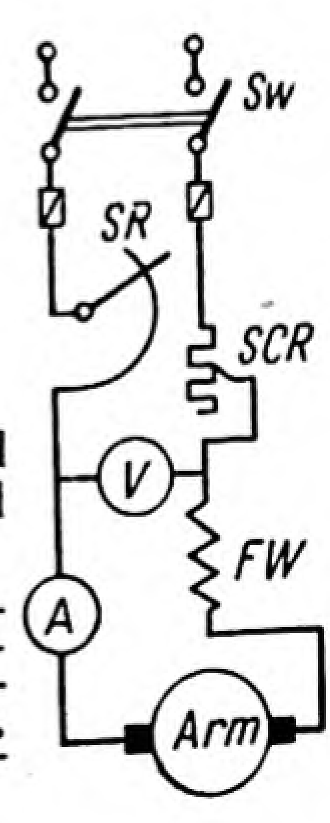


Fig. 299. Series-wound d-c motor starting and control circuit:
Arm — armature, *FW* — field winding, *SR*— starting rheostat, *SCR* — speed control rheostat, *Sw* — switch, *A* — ammeter, *V* — voltmeter.

enough to keep the speed within safe limits.

A specific characteristic of the series-wound motor is its ability to develop a high starting torque. By virtue of this it is mainly used on cranes and in electrified traction.

The speed of a series-wound motor can be changed by means of a speed control rheostat connected so that it is in series with the main circuit. However, this leads to considerable losses due to heating in the rheostat and is therefore uneconomical.

A more economical motor speed control method is to shunt the armature and series field windings with a rheostat (Fig. 300).

Thus, if the armature is shunted by closing switch S_2 and switch S_1 is left open, the current in the armature will be reduced owing to by-passing of part of the total motor current through the shunting resistance. By decreasing the current passed through the armature, we lower the speed of the motor.

When switch S_1 is closed with switch S_2 left open, the current passed through the series field winding will be reduced. This decreases the magnetic flux in the field poles and, as is known, raises the speed of the motor.

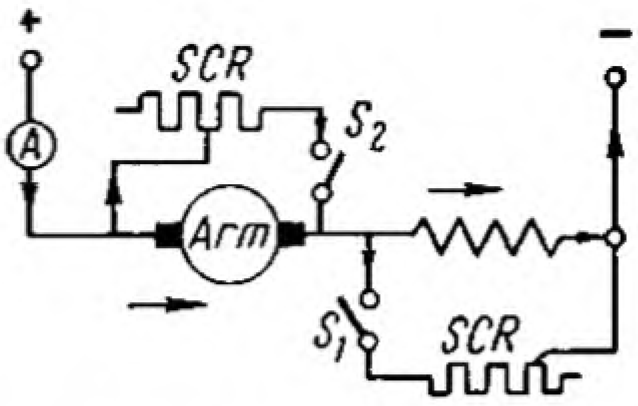


Fig. 300 Speed control circuit for series-wound d-c motor based on shunting of armature and field windings with resistances:

Arm — armature, *SCR* — speed control rheostat, *A* — ammeter, S_1 and S_2 — switches.

Reversal and Braking. Change in direction of rotation (or reversing) of a d-c motor is accomplished by changing the direction of the current either in the armature or in the field winding (Figs. 301, 302).

D-c motors are braked by either a mechanical or electric method.

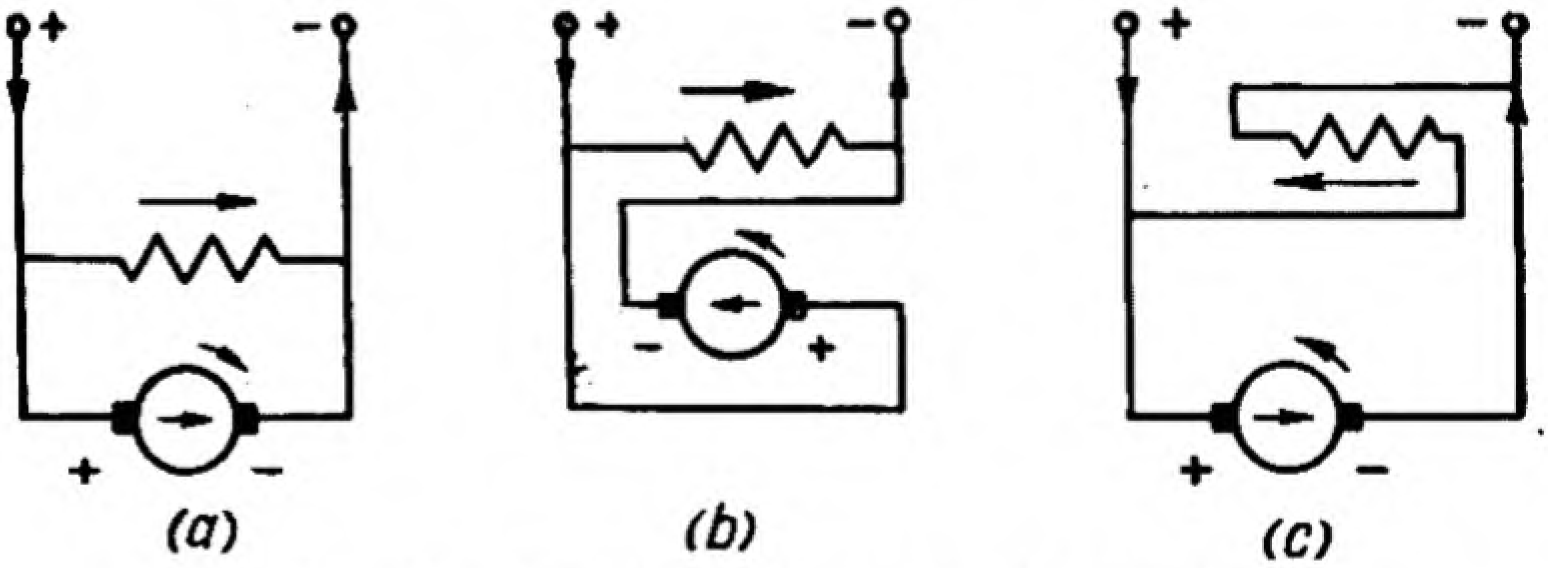


Fig. 301. Shunt-wound d-c motor reversing:

a—certain given direction of rotation, *b*—rotation when direction of current in armature winding is reversed, *c*—rotation when direction of current in field winding is reversed.

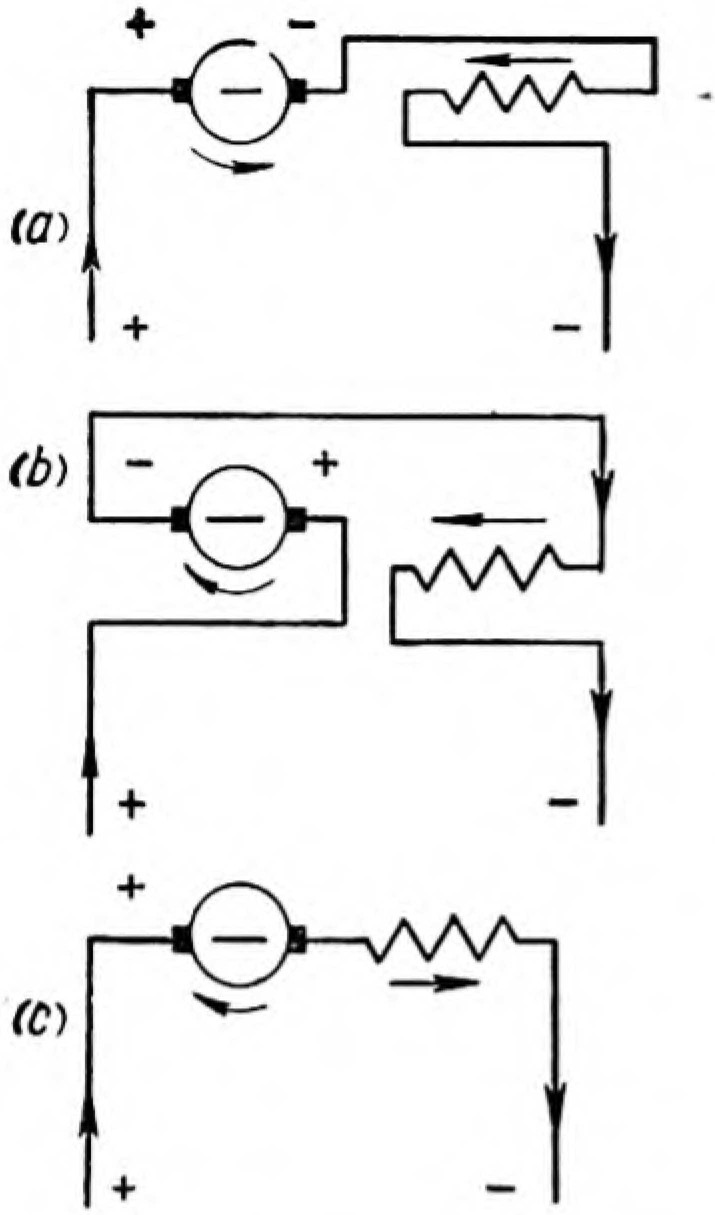


Fig. 302. Series-wound d-c motor reversing:

a—certain given direction of rotation, *b*—rotation when direction of current in armature winding is reversed, *c*—rotation when direction of current in field winding is reversed.

In the second case two fundamental means are available: dynamic braking and plugging (countercurrent braking).

Dynamic braking is based on switching of the motor over from power supply to connection with an external resistor to make it operate as a generator. When switch-over occurs, the mechanical energy previously stored in the moving parts of the motor and the mechanism coupled to it is expended partly in overcoming friction and partly in generating electric power (motor now operates as a generator). The power is dissipated in the external braking resistor.

The basic circuit for dynamic braking of a shunt-wound d-c motor is given in Fig. 303*a*. In the above circuit, when change-over switch *CS* is in position *1*, the machine operates as a motor. The instant the switch is thrown over to position *2* the machine begins to operate as a generator feeding into a circuit consisting of braking resistor *BR*, the armature winding and commutating pole windings *CP*.

The basic circuit for dynamic braking of a series-wound d-c motor can be seen in Fig. 303*b*.

Braking takes place in practically the same way as above. The difference is in that an auxiliary resistor *AR* is switched into the excitation circuit to prevent a large current from appearing in the field winding because of its small resistance.

Plugging (or countercurrent braking) consists in reversing the direction of the currents

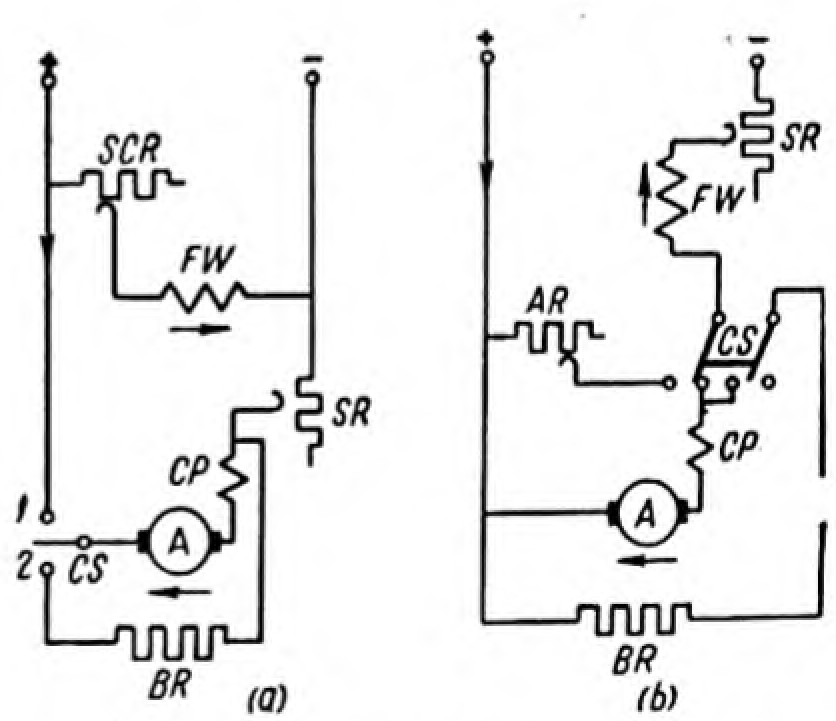


Fig. 303. D-c motor dynamic braking circuits:

a—with shunt-wound motor, *b*—with series-wound motor; *SR*—starting rheostat, *SCR*—speed-control rheostat, *FW*—field winding, *CP*—commutating pole winding, *BR*—braking resistor, *A*—armature, *CS*—change-over switch, *AR*—auxiliary resistor.

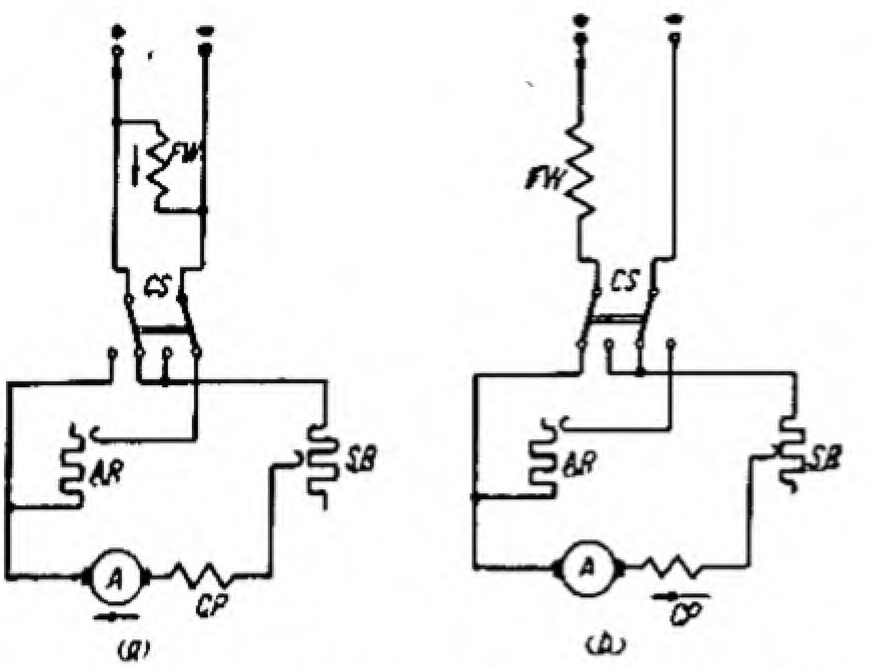


Fig. 304. Plugging circuits for d-c motors:
a—shunt-wound motor circuit, b—series-wound motor circuit.

flowing in the motor windings when the motor is still running. The result of such a switch-over of the motor is that it creates a torque on the rotor that opposes its forces of inertia.

Plugging circuits for braking shunt-wound and series-wound d-c motors are shown in Fig. 304. The auxiliary resistor *AR* switched in series with the armature serves to lower the current during plugging.

Slip-Ring Induction Motor Connections and Starting (Fig. 305). To accomplish a start, the starting-rheostat control lever must be set in its initial position, i.e., all the rheostat resistance must be cut in.

The brushes through which the rheostat is electrically connected to the rotor winding must also be lowered onto the slip rings.

The stator winding can now be switched on and the starting-rheostat resistance smoothly cut out. When the rheostat is fully cut out, the brushes are raised by turning the brush-lifting mechanism handle.

Shorting of the rotor winding occurs simultaneously with brush lifting, and all further operation of the motor is the same as that of a squirrel-cage motor.

As soon as a start has been accomplished, the starting

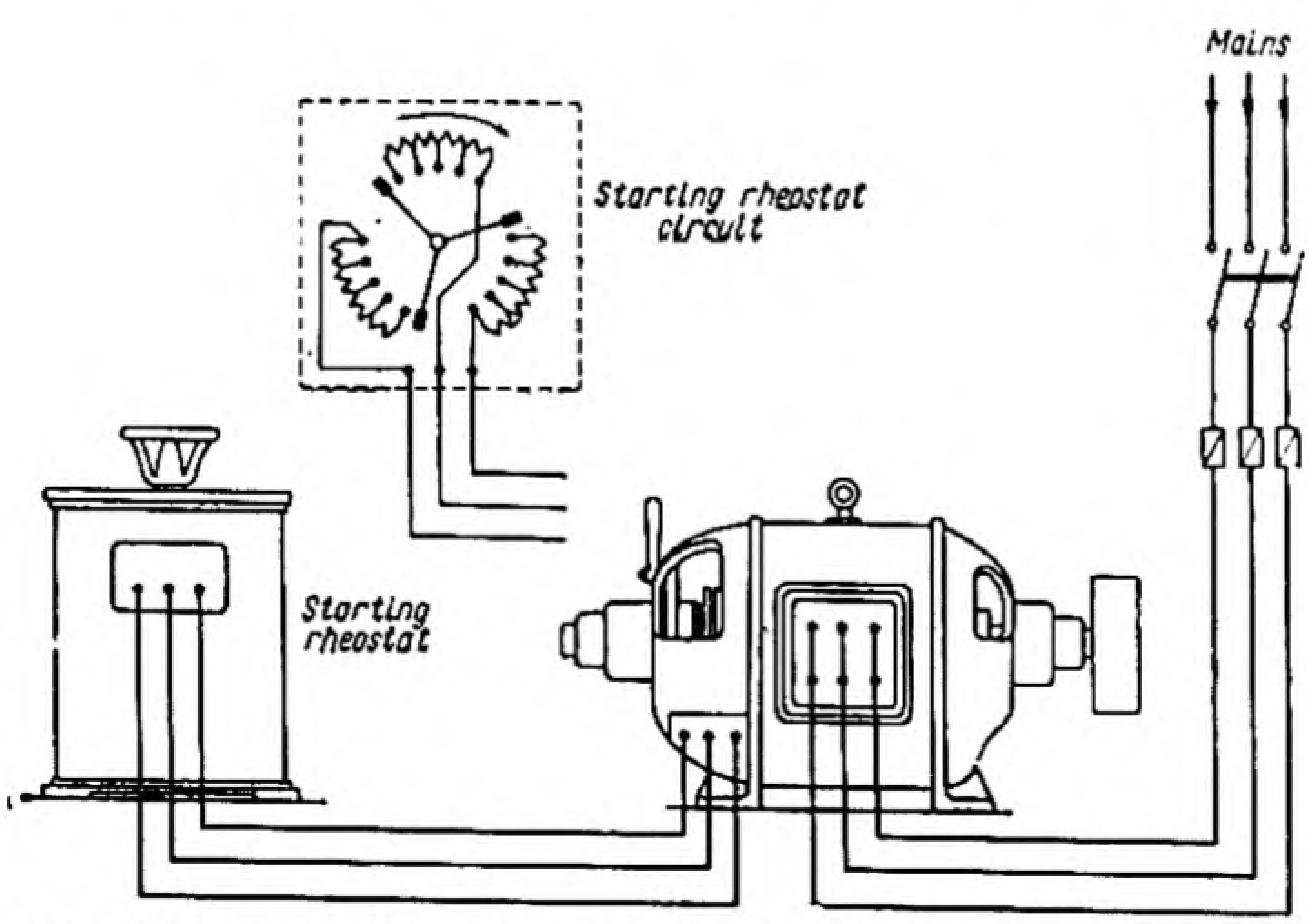


Fig. 305. Connections of a slip-ring induction motor for power supply and starting.

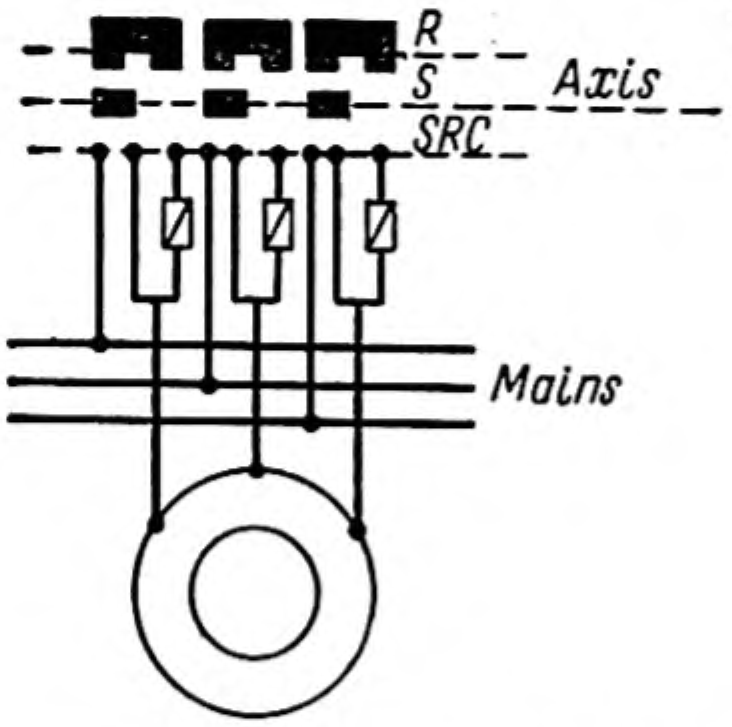


Fig. 306. Control scheme for starting squirrel-cage induction motor with fuses shunted:

SRC—start and running contacts, *S*—start bridging contacts, *R*—running make contacts.

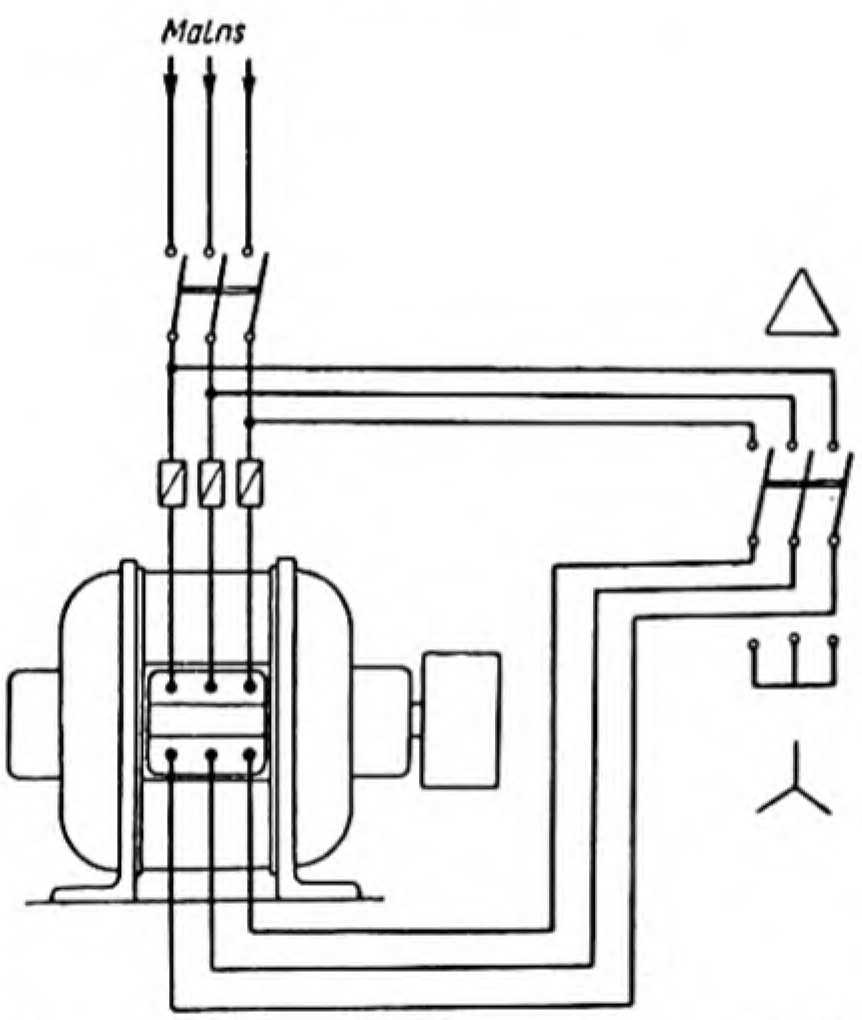


Fig. 307. Starting circuit for squirrel-cage induction motor started by change-over from star to delta connection.

rheostat handle must be returned to its initial position in which all the resistance is cut in.

To shut down the motor, the stator winding is disconnected from supply. When the motor stops, its brushes should be lowered to prepare for the next start.

Squirrel-Cage Induction Motor Connections and Starting. The starting current of a squirrel-cage induction motor exceeds 5 to 8 times its rated load current. Because of this, to prevent blow-out of the motor fuses, use is made of a circuit (Fig. 306) whereby the fuses are switched out during starting.

Fig. 307 shows the circuit used to connect a motor to supply for starting with a star-delta switch. When the motor is switched on, since it is in star connection, its starting current will be about three times smaller than when delta-connected.

When small induction motors must be reversed, it is necessary to interchange the connections of any two of the phases by means of a double-throw type switch (Fig. 308).

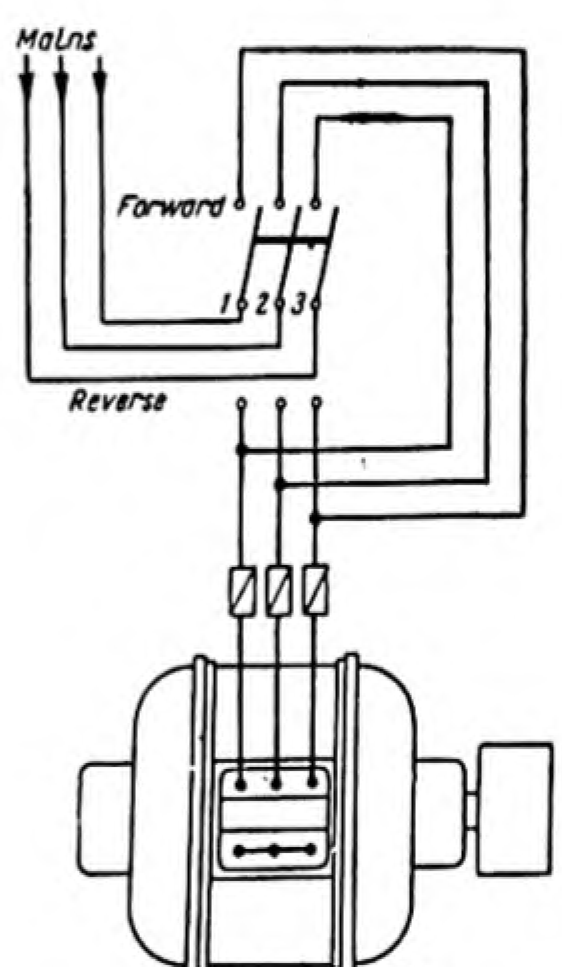


Fig. 308. Connections for reversal of squirrel-cage induction motor:

1, 2, 3—numerical order of phases.

Chapter XI

ELEMENTS OF AUTOMATIC ELECTRIC MOTOR CONTROL

1. Automatic Control of Asynchronous (Induction) Motors

One of the most widely used devices for automatic control of squirrel-cage induction motors is the magnetic starter, an apparatus in the form of an a-c contactor incorporating a thermal relay.

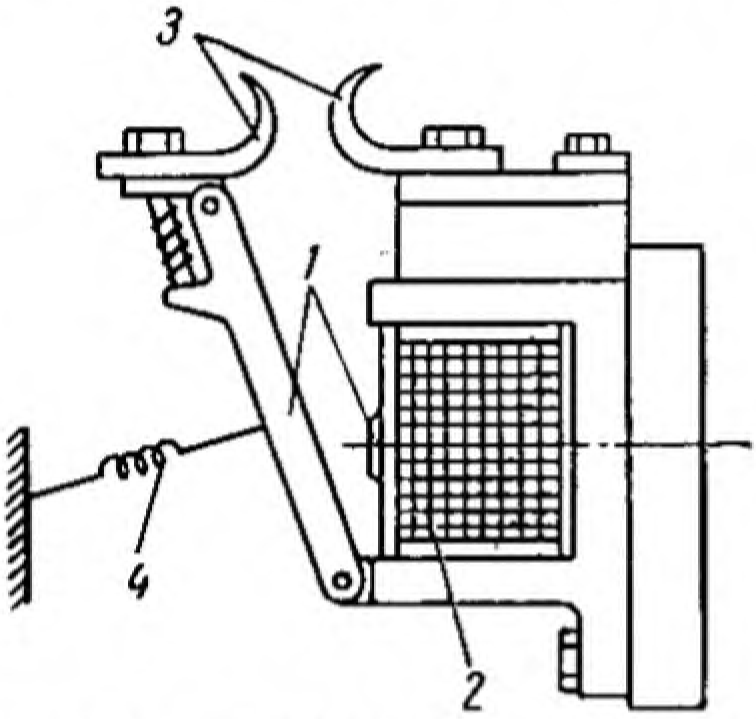


Fig. 309. Schematic diagram of contactor parts:
1—magnetic system, 2—operating coil, 3—contact parts, 4—spring.

A contactor is a remotely controlled electromagnetic switching device designed to be operated by push-button or automatic controls and serving for frequent closing and opening of power circuits during operative starting and stopping of electric motors.

A schematic diagram illustrating the basic parts of a contactor is given in Fig. 309. Its magnetic system *1* consists of a core and armature. When operating coil *2* is energised, the armature is attracted to the core and causes the contacts to close. On interruption of supply, the operating coil releases the armature which then drops backward under the force of its own weight and the tension of spring *4*. For the circuit connections of a three-pole contactor refer to Fig. 310.

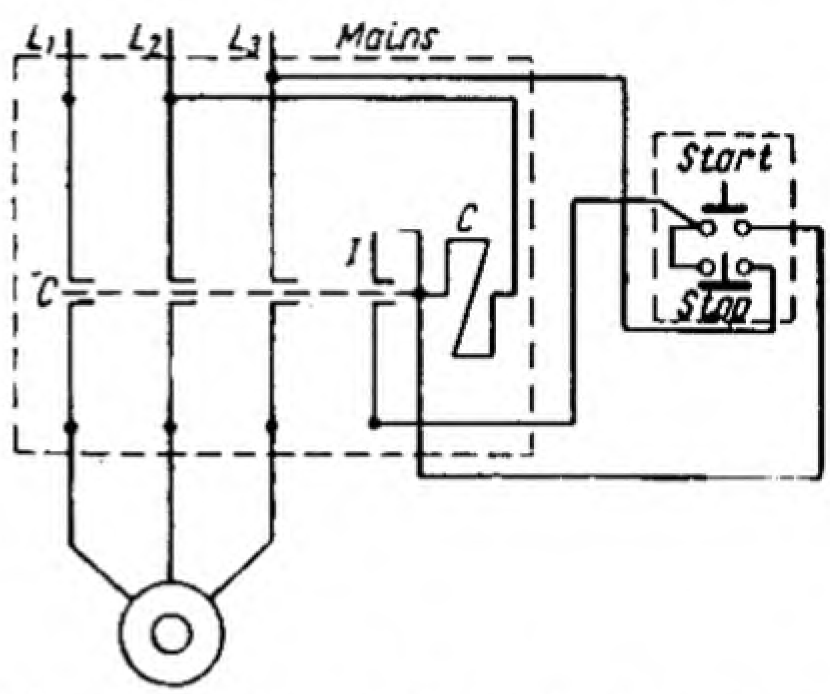


Fig. 310. Three-pole contactor connections.

The circuit connections in Fig. 310 show that when push-button "Start" is depressed, it completes a feed circuit for contactor operating coil *C*. This circuit starts at supply *L2*, passes through operating coil *C*, the contacts of the "Start" push-button, the normally-closed contacts of the "Stop" push-button, and ends at supply *L3*. Energised by the current allowed to flow through it, coil *C* makes the main contacts *C* close. Interlock *I* is closed simultaneously. When it closes, it shunts the "Start" button contacts. This makes it unnecessary to hold the button

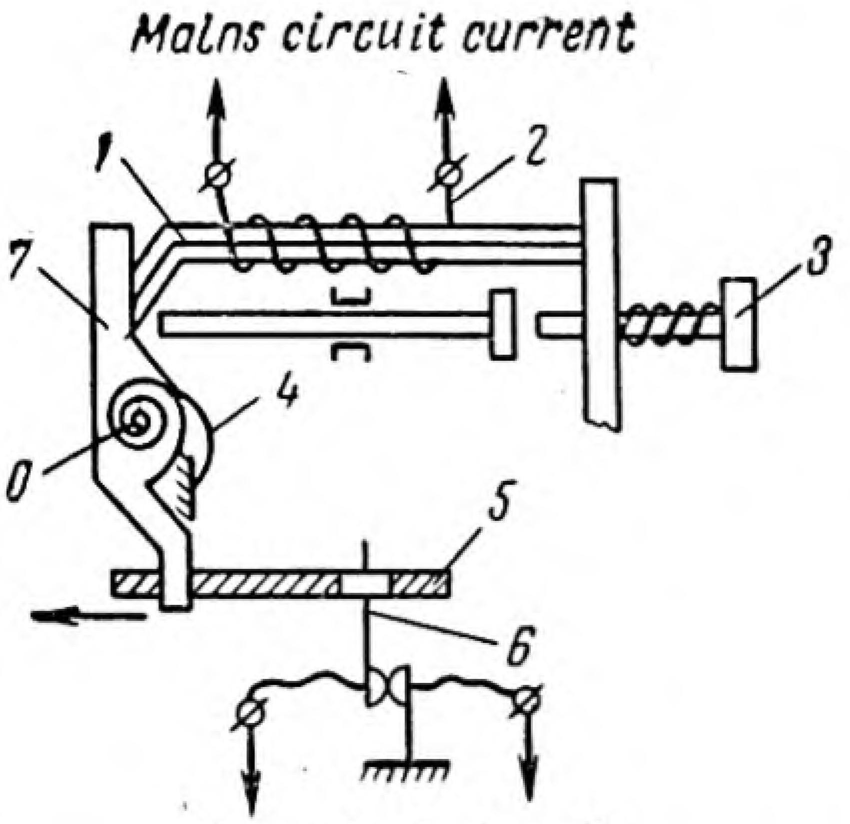


Fig. 311. Schematic diagram of a thermal relay.

down any longer. The contactor is opened by pushing the "Stop" push-button to break the supply circuit of contactor coil *C*.

The thermal relays built into magnetic starters are generally of the type based on change in shape of a bimetal strip under the action of a rise in temperature. A schematic representation of such a relay can be seen in Fig. 311.

In a thermal relay of the above type, any rise in current in a motor due to overload causes a rise in temperature of heating element *2* and bending of the bimetal strip so that it moves upward out of engagement with the latch heel of lever *7*. Unlatched, lever *7* turns, under the force of spiral spring *4*, about axis *0* to move linkage member *5* in the direction indicated by the arrow and thus open normally-closed relay contacts *6* and break the control circuit. Button *3* brought out above the body of the relay serves to reset (relatch) the relay after a drop-out operation.

Thermal relays (see *TR* in Figs 313 and 314) serve only for protection against overloads. They do not provide protection from short-circuit currents.

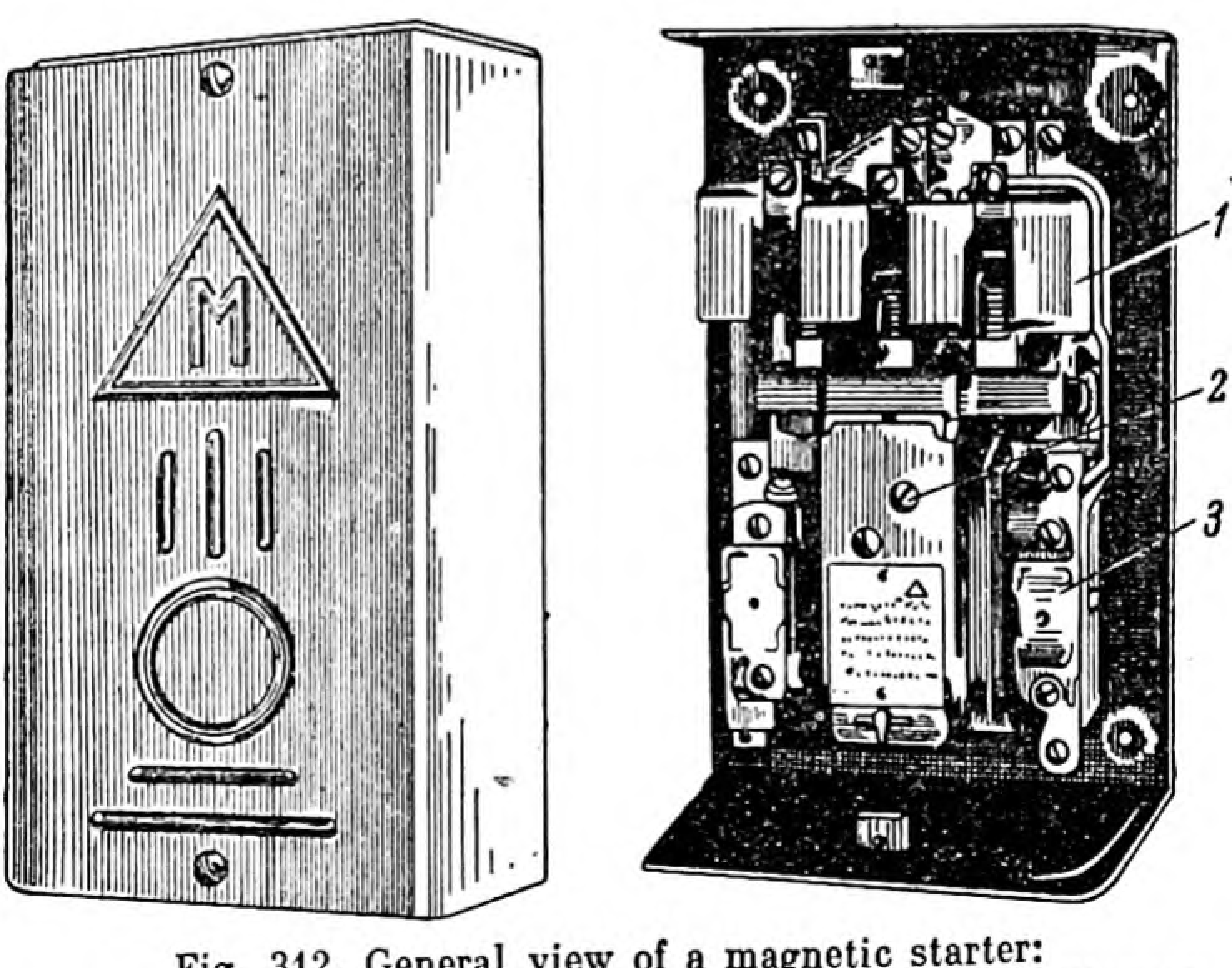


Fig. 312. General view of a magnetic starter:
1—main (power) contacts, *2*—thermal relay reset button, *3*—thermal relay.

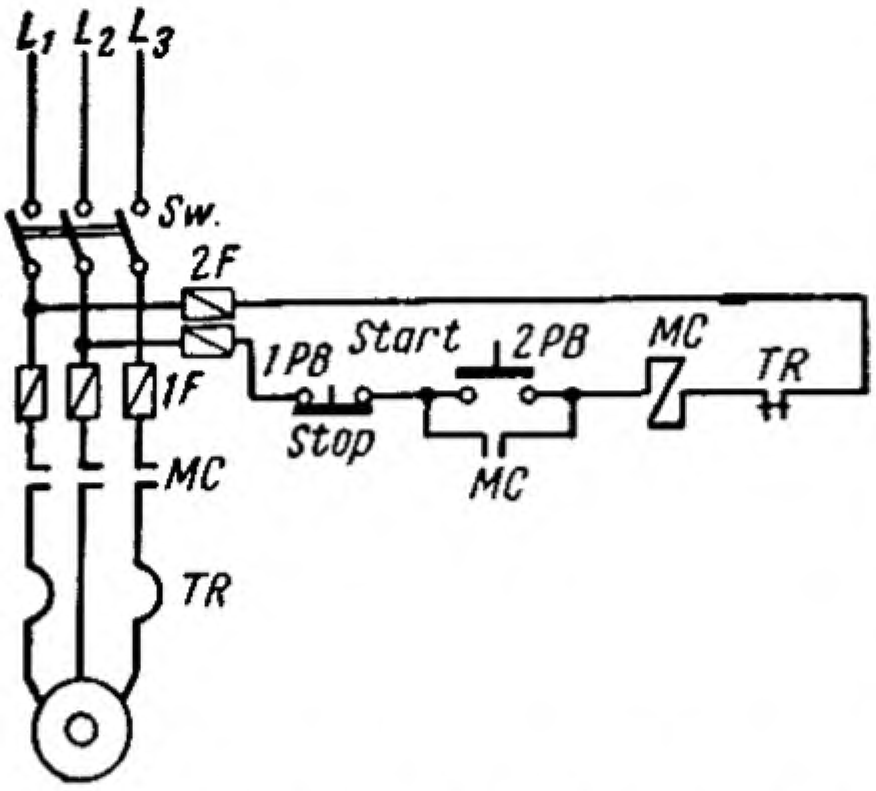


Fig. 313. Simplified induction motor control circuit using a magnetic starter.

A general view of a magnetic starter can be seen in Fig. 312.

Fig. 313 gives a simplified control circuit for a squirrel-cage induction motor in which control is accomplished with a magnetic starter. To start the motor, mains switch *Sw* is closed to connect the power and control circuits to supply. Next, the supply circuit for motor-contactor operating coil *MC* is completed by pushing "Start" push-button *2PB*. This results in closing of motor-contactor power contacts *MC* and connection of the motor to supply. The above action occurs with simultaneous closing of interlock *MC* which serves to shunt the "Start" *2PB* button contacts and makes it unnecessary to hold the button depressed any longer.

Fuses *1F* and *2F* in the circuit protect the motor against short-circuit currents.

A magnetic starter also acts as a device which prevents a motor from self-restarting after switch-out caused by a drop or sudden disappearance of supply voltage. In such cases the magnetic attraction of the operating coil becomes too weak to hold the armature in, the latter therefore drops out, opens the contactor and disconnects the motor from supply.

For starting a motor in any one of two directions ("Forward" and "Reverse"), a reversing type of magnetic starter is used. It consists of two contactors: *FC*—for forward rotation, and *RC*—for reverse rotation.

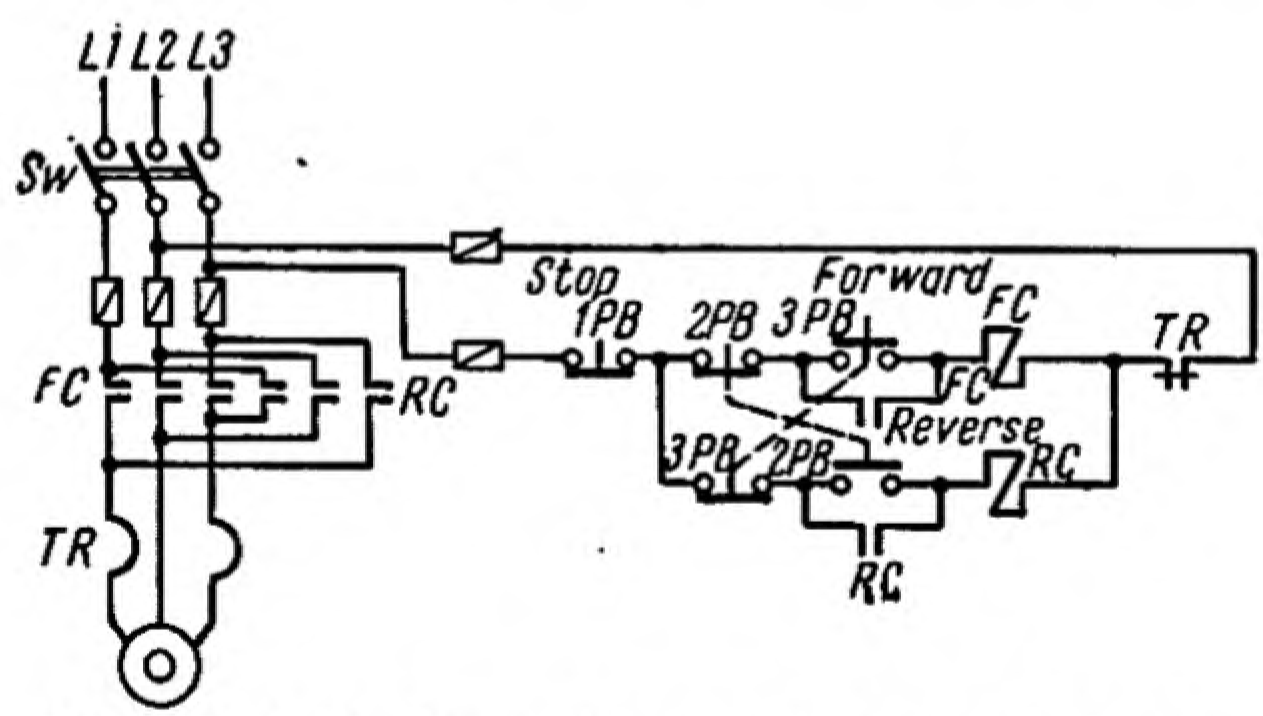


Fig. 314. Induction motor reversing control circuit.

A circuit for reversing control of an induction motor can be seen in Fig. 314.

By means of such a circuit the motor is started by closing mains switch *Sw* and pressing "Forward" push-button *3PB* (for forward rotation). The latter completes the circuit for energising forward-contactor operating coil *FC*. Forward contactor *FC* then closes and connects the motor stator to power supply through its main contacts *FC*. Simultaneously closed is interlock *FC* of the same contactor which shunts the contacts of forward push-button *3PB* to form a holding circuit and eliminate the need for continuing to hold the button down.

To reverse the direction of motor rotation, "Reverse" push-button *2PB* is depressed to complete the supply circuit and energise reverse-contactor operating coil *RC*. This causes the contactor to close and connect the motor again to the supply circuit, this time with two of the phases interchanged.

Simultaneous closing of both contactors, *FC* and *RC*, cannot occur. "Forward" push-button *3PB* has a second pair of normally-closed contacts connected in the circuit of operating coil *RC*. "Reverse" push-button *2PB* likewise has a second pair of normally-closed contacts connected in the circuit of operating coil *FC*. Serving as interlocks, either of the above normally-closed contacts open when its push-button is depressed and thus cut off any supply to the other operating coil; operation of *3PB* to close *FC* cuts off supply to *RC* and operation of *2PB* to close *RC* cuts off supply to *FC*.

Automatic control of slip-ring induction motors can be accomplished either with control devices operated by direct current or by alternating current.

D-c operated control apparatus provides high reliability but requires a special source of d-c operative power. Due to this, it is used only on drives of vital or key nature for which very high reliability is the main consideration.

In the usual cases a-c controlled apparatus is employed. In particular, wide use is made of a relatively simple scheme of control (Fig. 315).

As can easily be seen, in the above control circuit the motor stator is connected to supply by a three-pole contactor, indicated by its three main contacts *MC* and its operating coil *MC*.

A set of resistances divided into three steps in each phase has been provided in circuit with the rotor.

For shorting the steps of resistance during a start, the circuit incorporates three two-pole accelerating contactors *1A*, *2A* and *3A* which are switched into the circuit with the aid of pendulum-type time-lag relays attached on contactors *MC*, *1A* and *2A* for time control purposes.

To protect the motor against short circuits and overloads, overcurrent relays (*OLR*) are incorporated.

The starting process is initiated by pushing the "Start" push-button. The latter completes the circuit: phase *L1*, fuse F_1, normally closed contacts of push-button "Stop", shorted contacts of depressed "Start" push-button, motor-contactor operating coil *MC*, contacts of overcurrent relays OLR_1 and OLR_2, fuse F_2 and phase *L2*.

Energised by the flow of current through it, the operating coil closes motor contactor *MC* to connect the motor to the supply: all the starting resistance is in circuit with the rotor.

Operation of motor contactor *MC* makes it close its interlock I_{MC} which serves as the "hold-in" contact and allows the "Start" push-button to be released as the start is initiated.

When motor contactor *MC* is operated, it brings its attached pendulum relay *MCPR* into action. After elapse of a given, set time delay, the latter closes its normally open contacts and completes the circuit: phase *L1*, fuse F_1, normally closed contacts of push-button "Stop", interlock I_{MC}, closed contacts of pendulum relay *MCPR*, accelerating-contactor coil *1A*, fuse F_2 and phase *L2*. Since the operating coil of accelerating contactor *1A* will now

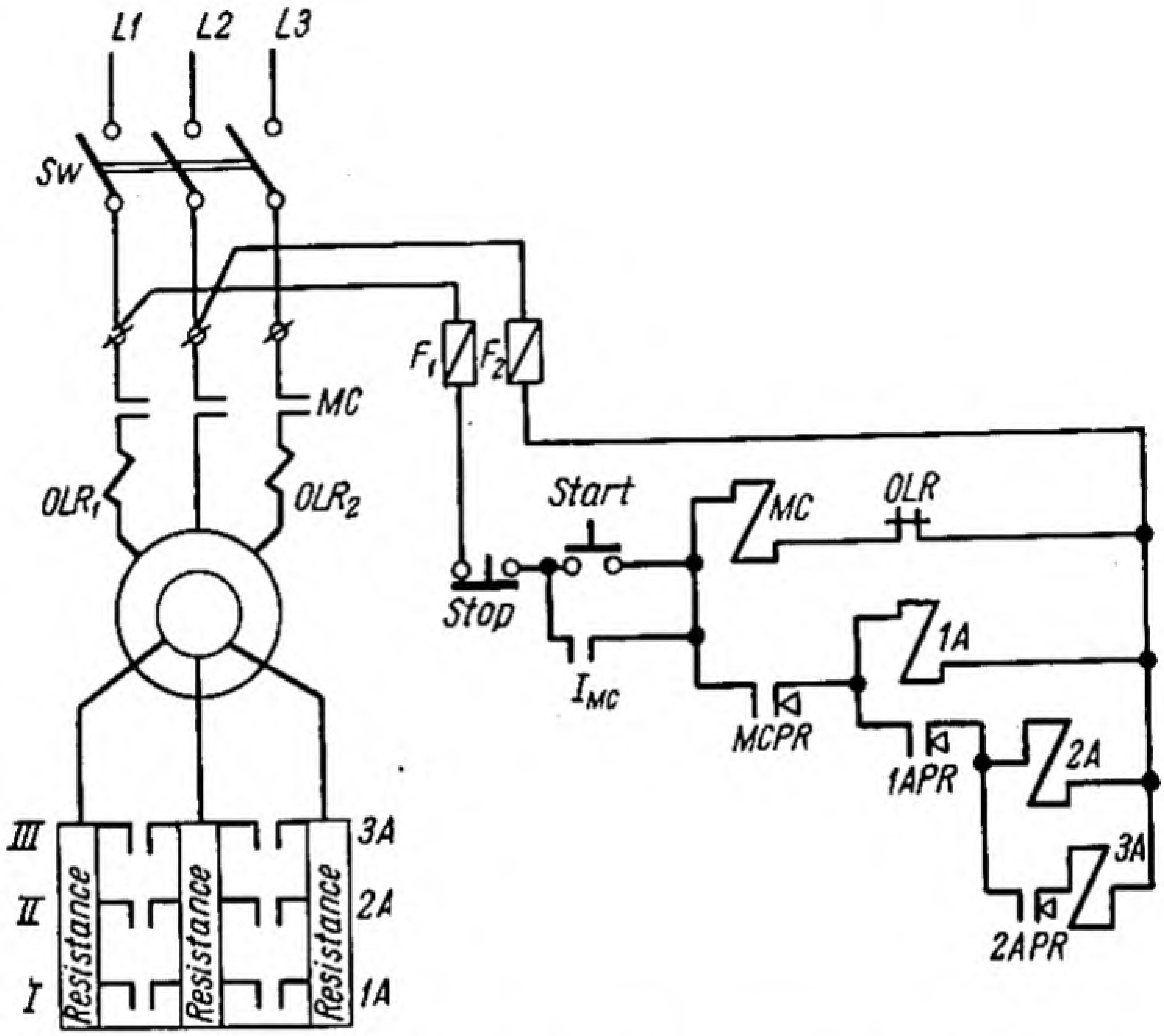


Fig. 315. Slip-ring induction motor automatic control circuit.

be energised by the resultant flow of current, contactor *1A* is closed and shorts out the first step of resistance *1A* in all three phases of the rotor.

The instant contactor *1A* is caused to operate, it brings its attached pendulum relay *1APR* into action. After a fixed interval of time delay, the latter completes the circuit: phase *L1*, fuse F_1, normally-closed contacts of push-button "Stop", interlock I_{MC}, closed contacts of pendulum relays *MCPR* and *1APR*, operating coil of accelerating contactor *2A*, fuse F_2 and phase *L2*. This results in closing of accelerating contactor *2A* by operating coil *2A* and in shorting out of the second step of resistance in the rotor circuit by main contacts *2A*.

In the same manner as above, pendulum relay *2APR* is operated to close accelerating contact *3A*, short out the third step of resistance in the rotor circuit and thus fully short circuit the rotor and complete the starting process.

To stop the motor, it is only necessary to push the "Stop" push-button. By this, the supply circuit to the motor-contactor operating coil *MC* is broken and the contactor drops open.

In the event of a short circuit or overload, the motor will be disconnected from power supply by overcurrent relays OLR_1 and OLR_2 which, by opening of their normally-closed contacts, can also de-energise the operating coil of motor contactor *MC*.

2. *Automatic Control of D-C Motors*

Automatic Control of a Shunt-Wound D-C Motor (Fig. 316). In the circuit given in Fig. 316 supply is switched on to the main and control circuits by closing mains switch *Sw*. By next pushing "Start" push-button *2PB* motor contactor *MC* is operated. Its main (power) contacts *MC* then close the main

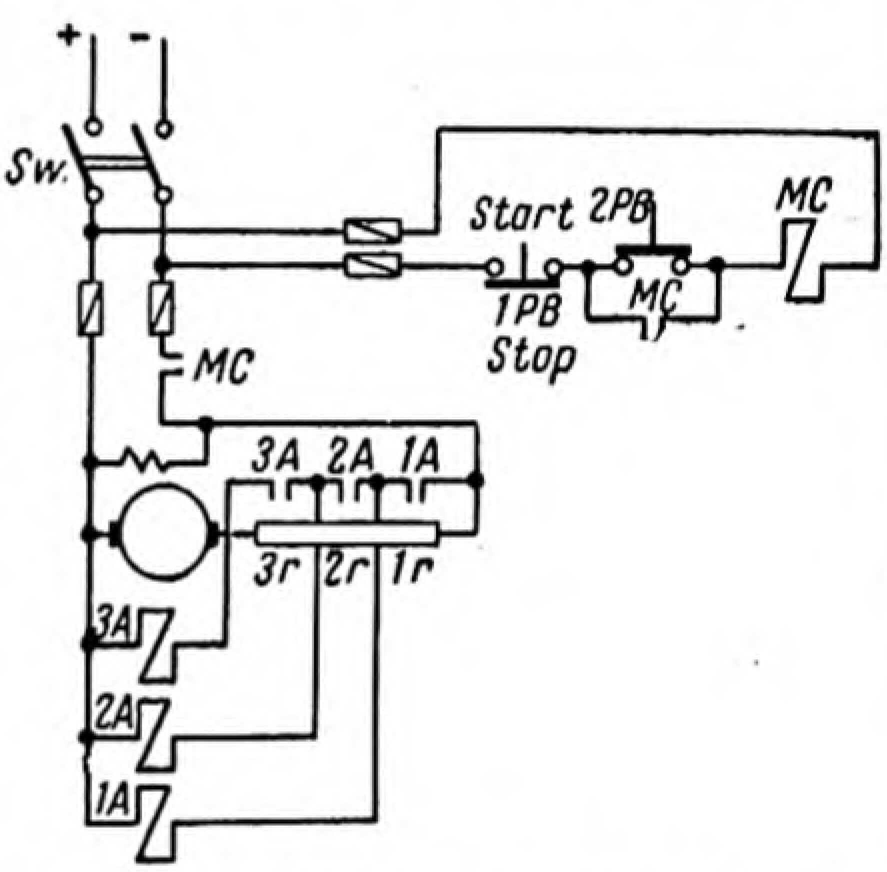


Fig. 316. Shunt-wound d-c motor automatic control circuit (simplified).

circuit and thereby switch the motor on.

As the motor begins to gain speed, accelerating contactor *1A*, due to the fact that it is caused to operate first, closes its normally-open contacts *1A* to short out the first step of starting resistance *1r*.

Further rise in motor speed leads to subsequent operation of accelerating contactors *2A* and *3A*, this resulting in corresponding closing of their normally-open contacts *2A* and *3A* and in shorting out first

the second-step starting resistance $2r$ and then the third-step starting resistance $3r$.

As soon as all three steps of the starting resistance have been shorted out, the start is completed and the motor begins to operate under its normal running conditions.

Automatic Control of a Series-Wound D-C Motor (Fig. 317). By closing mains switch *Sw* shown in the figure, the supply voltage is applied to the main (power) and control circuits, and the coil of time lag relay *1TLR* is energised. This makes it open its normally-closed contact *1TLR*.

As soon as "Start" push-button *2PB* is depressed to initiate the start, motor-contactor operating coil *MC* is energised, closes the motor contactor and thereby connects the motor to the supply through its normally open main contact *MC*. The above operation simultaneously connects the coils of time lag relays *2TLR* and *3TLR* to supply and the relays open their contacts.

Also simultaneously performed during the above operation is shorting of the *1TLR* time lag relay coil by motor-contactor main contact *MC*. The relay, now de-energised, recloses its normally-closed contact with a given time delay to complete a circuit branch for energising the *1A* accelerating-contactor operating coil. The *1A* contactor then operates and its normally open contacts *1A* short the first step $1r$ in the starting resistance.

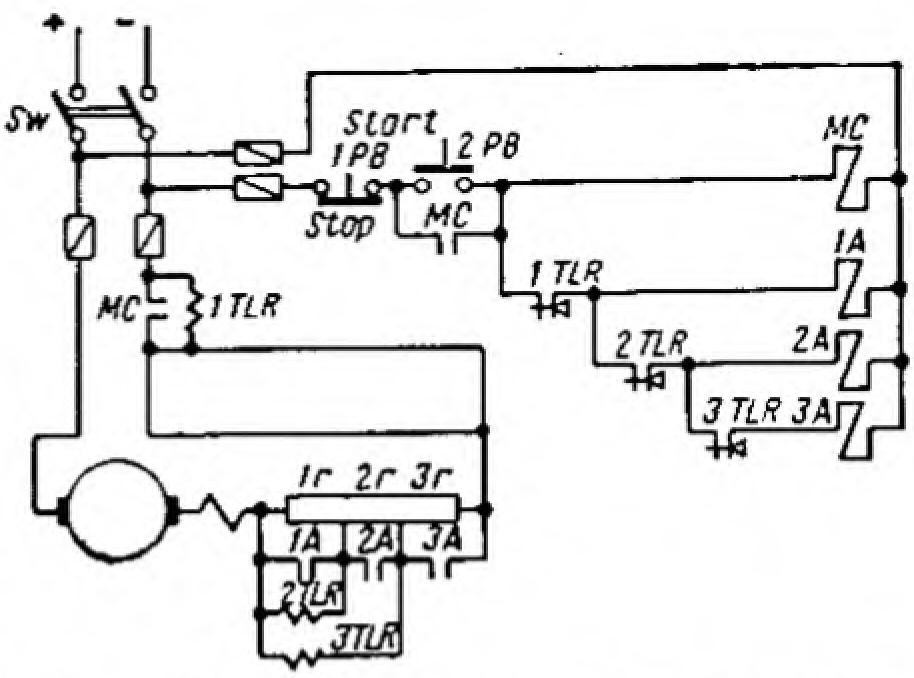


Fig. 317. Series-wound d-c motor automatic control circuit (simplified).

When the control circuit reaches this stage of operation, time lag relay *2TLR* recloses its contacts because its operating coil has been shunted by accelerating-contactor contact *1A*. This results in completing of the energising circuit to the *2A* accelerating-contactor operating coil with subsequent closing of main contact *2A* and shorting of the second step $2r$ in the starting resistance.

In the same manner, by means of time lag relay *3TLR* and the third accelerating contactor *3A*, the last step ($3r$) of the starting resistance is shorted. This last operation completes the start.

3. Motor Controls for Industrial Mechanisms

Certain parts of work mechanisms or machinery such as, for example, the slide of a broaching machine, the bridge or the trolley of an overhead travelling crane, require that their travel be limited (see control circuit in Fig. 318).

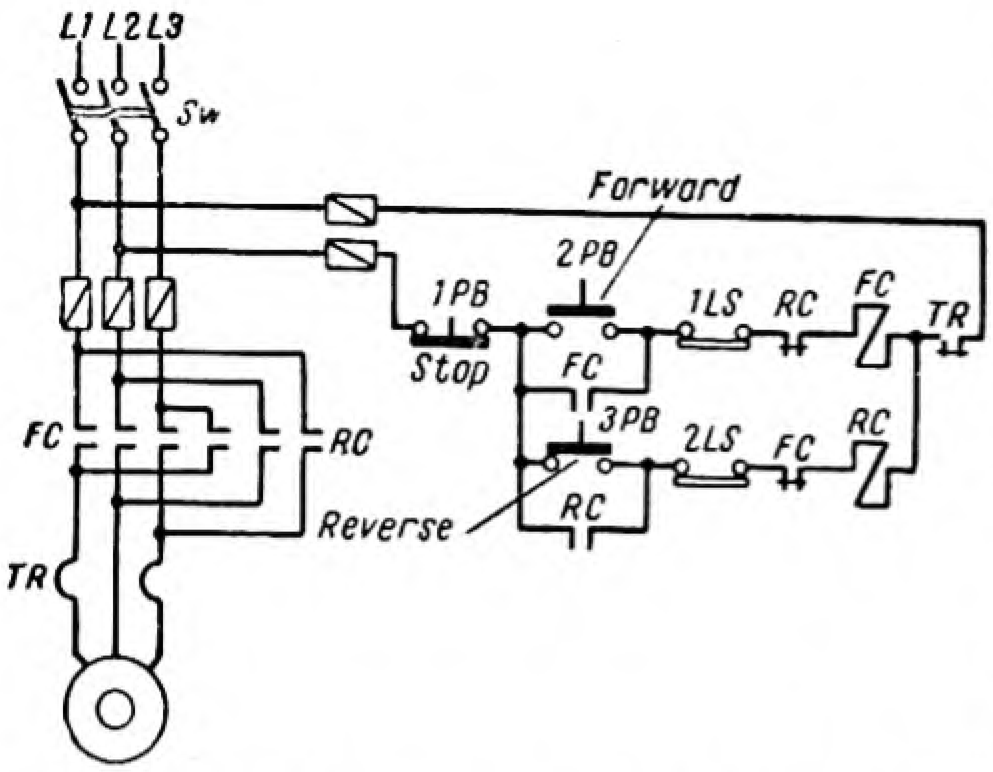


Fig. 318. Control circuit of a squirrel-cage induction motor by which some given element of the work mechanism can have only limited travel.

For this, the motor, when run in a given direction, must be switched off the instant the mechanism or unit approaches its extreme position or limit of travel. Switch-off takes place as the result of a stop running up against or over the corresponding actuating part of a special limit switch such as that represented by *1LS* or *2LS* in the above-mentioned control circuit. When one of the limit switches, depending upon the direction of rotation or travel, has its normally-closed contacts tripped open, it de-energises the corresponding operating coil of "Forward" contactor *FC* or "Reverse" contactor *RC*. This results in disconnection of the motor from supply and in its shut-down.

Any possibility of closing both the "Forward" and the "Reverse" contactors at the same time is excluded by interposing the normally-closed interlock *RC* in the *FC* operating coil circuit and, conversely, interposing the *FC* normally-closed interlock in the circuit of the *RC* operating coil circuit.

Squirrel-cage induction motors can be quite simply braked by a plugging control circuit (Fig. 319).

The braking control is accomplished with a reversing magnetic starter comprising two contactors *1C* and *2C* (see Fig. 319).

When mains switch *Sw* is closed in the above-mentioned circuit and "Start" push-button *2PB* depressed, the *1C* contactor operating coil is energised and the motor started. As the motor speed begins to rise, speed relay *SR* picks up to close its normally-open contacts and thus prepare a circuit for energising the *2C* plug-

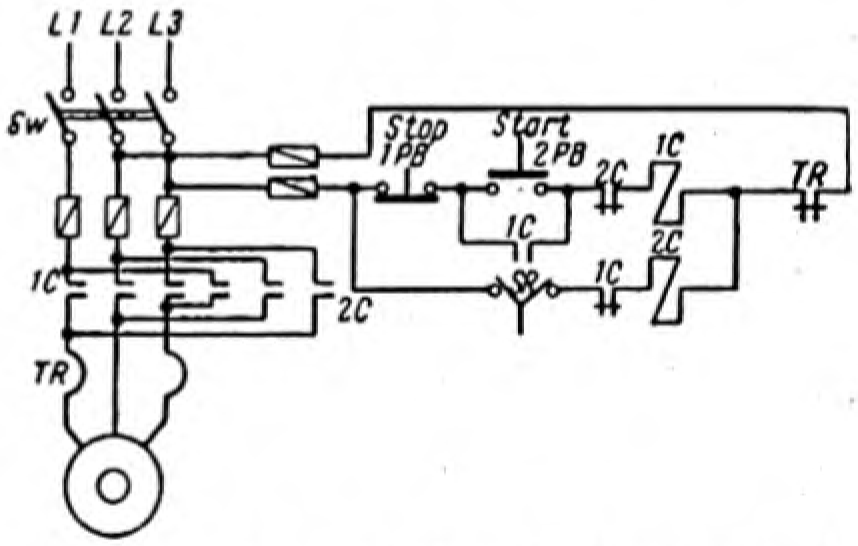


Fig. 319. Control circuit of a squirrel-cage induction motor to be braked by plugging (countercurrent).

ging-contactor operating coil, but not yet energising it because interlock contact *1C* was opened prior to this by the closing of contactor *1C*.

The instant "Stop" push-button *1PB* is depressed, contactor *1C* drops open and its interlock *1C* returns to its nor-

mally-closed position. This results in closing of the circuit for supply to the $2C$ contactor operating coil and leads to contactor $2C$ reconnecting the motor to supply with two of the leads now interchanged (start in reverse direction). This reversed connection, under the control of speed relay SR, creates the necessary torque for braking the motor without reverse rotation.

Simultaneous closing of contactors $1C$ and $2C$ is precluded because the $1C$ contactor operating coil circuit is broken by opening of normally-closed interlock $2C$ when contactor $2C$ is closed. The final switch-off of the motor is accomplished with speed relay SR, the contacts of which open when the motor loses its speed.

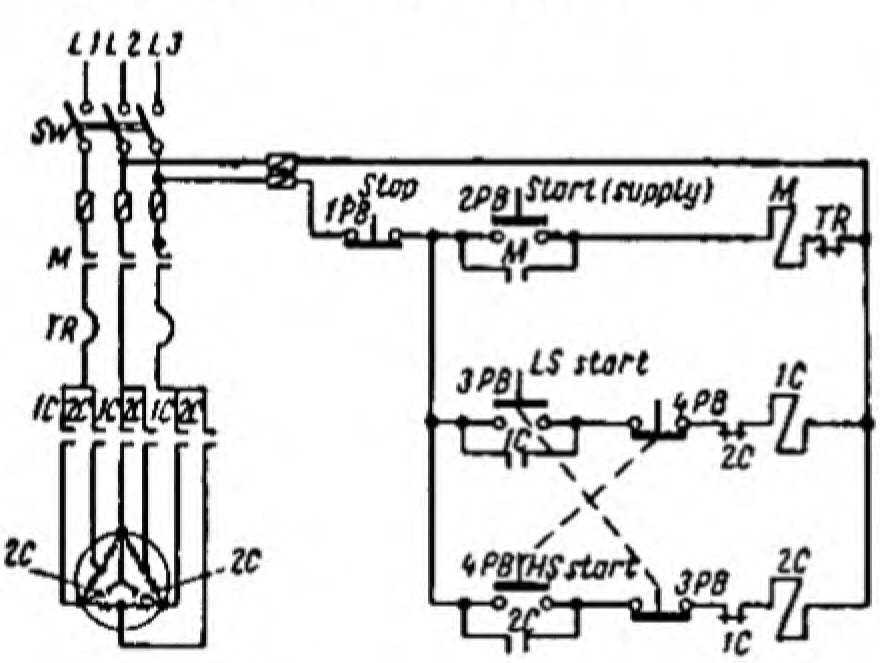


Fig. 320. Control circuit of a two-speed squirrel-cage induction motor.

In electric drive practice a great many operating mechanisms and machines are equipped with a multi-speed induction motor. One of the control circuits for such a motor (two-speed) is shown in Fig. 320.

When in the above circuit mains switch Sw is closed and push-button $2PB$ is depressed, main contactor M closes to prepare the motor for its start. By next pushing LS *start* push-button $3PB$, the operating coil of contactor $1C$ is energised through the circuit completed by push-button $3PB$. This closes contactor $1C$ to make its main contacts $1C$ switch the motor on for rotation at low speed (LS).

If the motor speed must be raised, HS *start* push-button $4PB$ is pushed. By this a supply circuit is closed for the operating coil of contactor $2C$. Contactor $2C$ then operates to close main contacts $2C$ in the supply circuit and also have its auxiliary contacts $2C$ complete a neutral-point connection by which the motor winding becomes double-star connected. Under these conditions the motor runs at higher speed (HS).

Mechanisms are frequently operated not only by one, but by several motors. This makes it necessary to have them operate in definite combinations.

When the two motors of a machine tool must operate only one at a time, this control can be accomplished very simply by connecting the normally-closed interlock of the first motor contactor into the operating-coil circuit of the second motor contactor and, conversely, connecting the normally-closed interlock of the second motor contactor into the operating-coil circuit of the first motor contactor (Fig. 321).

If a motor must only operate after the first motor has been

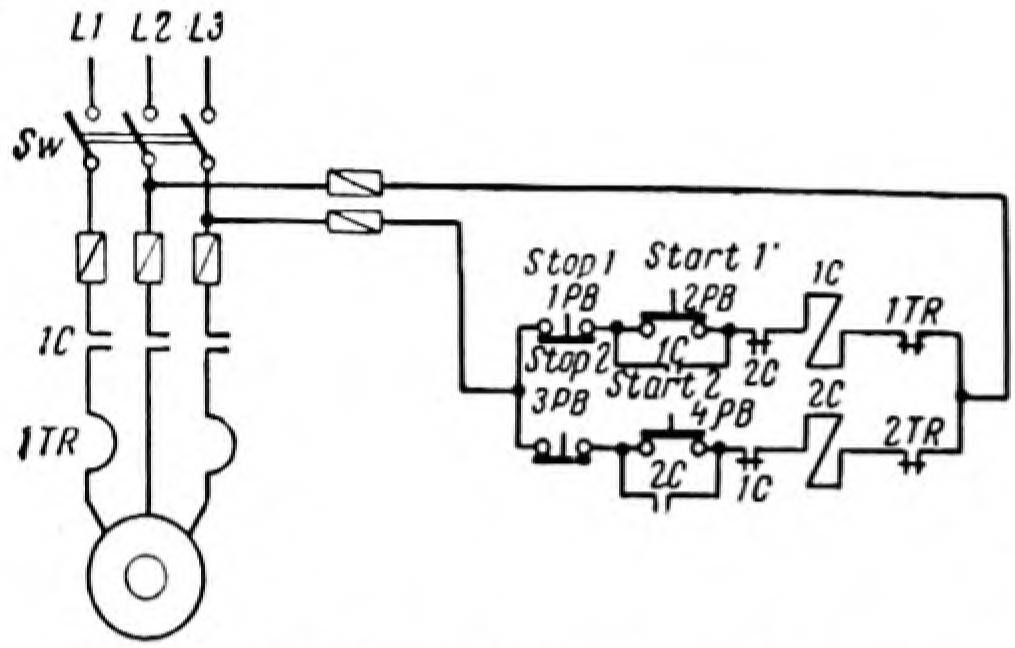


Fig. 321. Control circuit for two induction motors of which only one can be started at one time.*

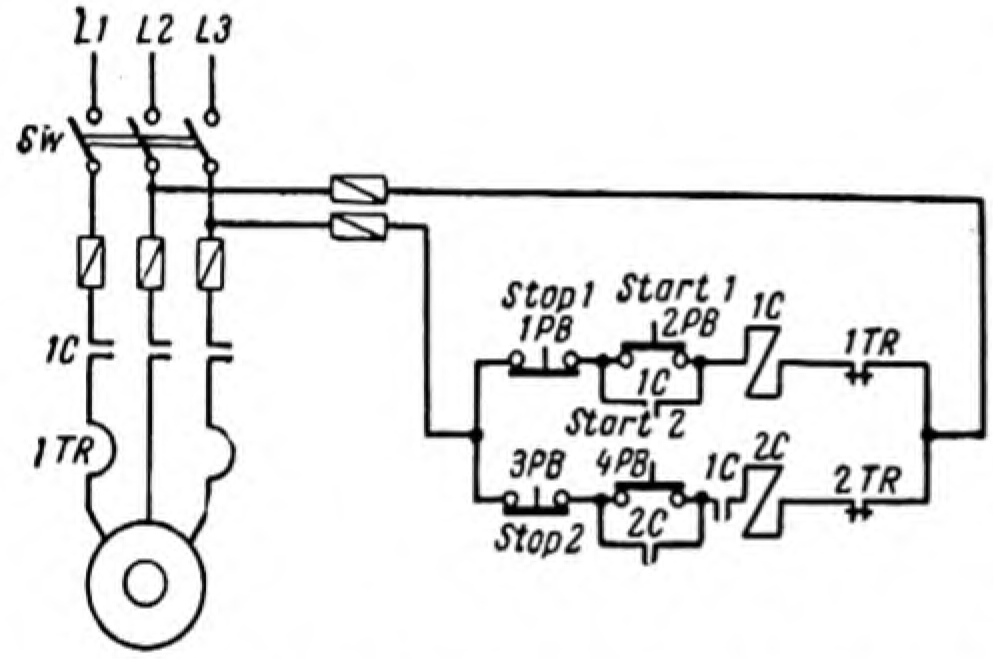


Fig. 322. Control circuit by which one motor can operate only after the start of another motor.*

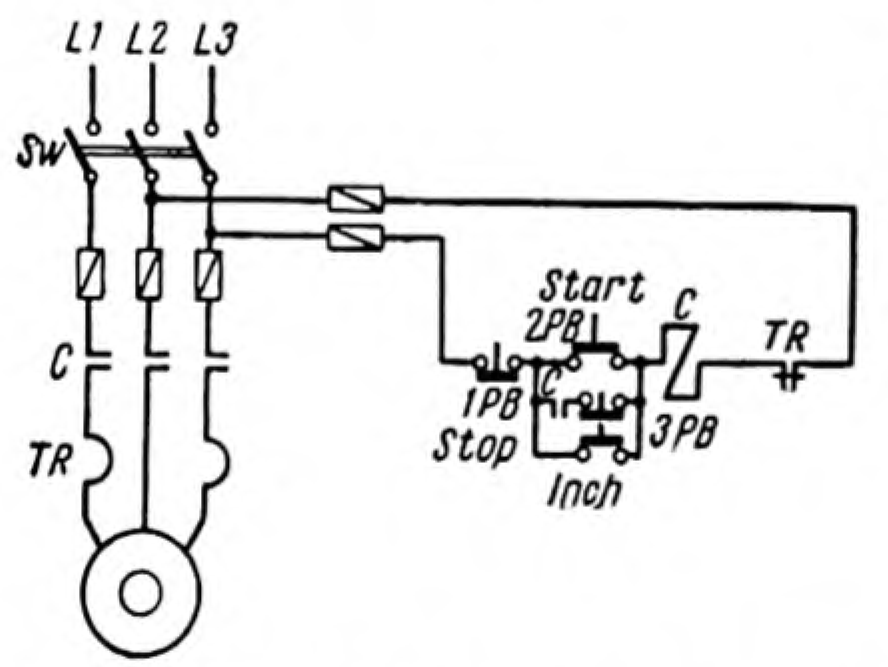


Fig. 323. "Inching" control circuit for an induction motor.

switched on (Fig. 322), this is achieved by connecting the normally-open interlock of the first motor contactor *1C* into the operating-coil circuit of the second motor contactor *2C*.

When a motor must be "inched" or "jogged" (during setting-up work on its machine), the control circuit (Fig. 323) incorporates an additional "Inch" push-button with two pairs of contacts. As soon as the "Inch" button is depressed, one pair of its contacts (the normally-closed pair) opens first to break the operating-coil holding circuit. This makes motor starting and stopping now dependent only on whether the other pair of contacts makes or breaks a circuit branch for energising the operating coil.

Rules for safety often require that the operator of a certain machine must be compelled to use both hands in order to start the motor (for example, the motor of a guillotine shearing machine, a machine on which there is a very high risk of the free hand of the operator being accidentally left under the knife). In such cases the motor must, therefore, be started by means of two "Start" push-buttons connected in series.

4. Operation of Electric Drives with Automatic Electronic-Ionic and Rotary-Machine Controls

In addition to relay-contactor systems, modern electric drives are also designed with

* Circuits in Figs 321 and 322 show only one motor. The second motor is connected through its own contactor in parallel with the first motor.

electronic-ionic controls by means of which electric motors can be operated over a much wider speed range.

A drive equipped with electronic-ionic control apparatus can be termed an electronic-ionic or ionic motor drive. This type of drive can be found in metalworking, machine-tool paper, textile and other industries.

One of the electronic devices very widely used in control schemes for the above-mentioned drives is a three-electrode valve or triode, a device differing from the usual two-electrode valve in that it has a third electrode in the form of a control grid placed between the cathode and the plate. Provision of the grid creates the possibility of control action upon the stream of electrons which travel from the cathode to the plate. It is this feature that is utilised for motor control.

A triode which has its bulb filled with mercury vapour or an inert gas is called a thyratron (Fig. 324). The simplest of circuits containing a thyratron is shown in Fig. 325.

As can be seen from the diagram, thyratron T is used in conjunction with a series transformer ST interposed in the load circuit connected to a-c supply. When a current cannot flow through the secondary of this transformer (thyratron locked out), the greatest part of the voltage drop in the a-c circuit occurs across the series transformer primary, the voltage drop across the primary of the loading transformer LT being very small in proportion. The instant the thyratron is ignited (unlocked) its discharge current shunts the series transformer. This redistributes the voltage drop in the a-c circuit. The greatest voltage drop now appears across the loading transformer primary, only a small part of the total voltage being found across the series transformer primary.

By adjusting the thyratron grid voltage to regulate the current in the series transformer secondary, control is obtained over the magnitude of the load current.

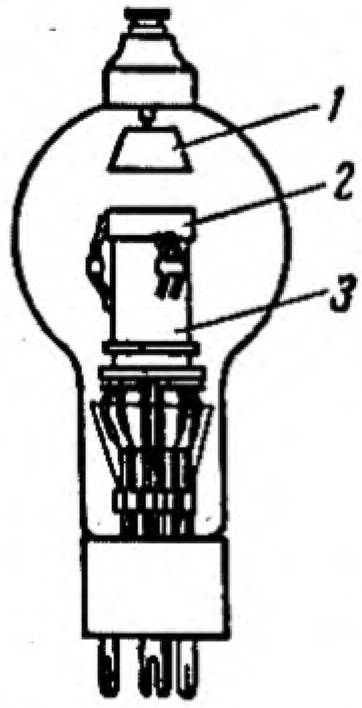


Fig. 324. Parts of a thyratron:
1—plate, 2—control grid, 3—screen.

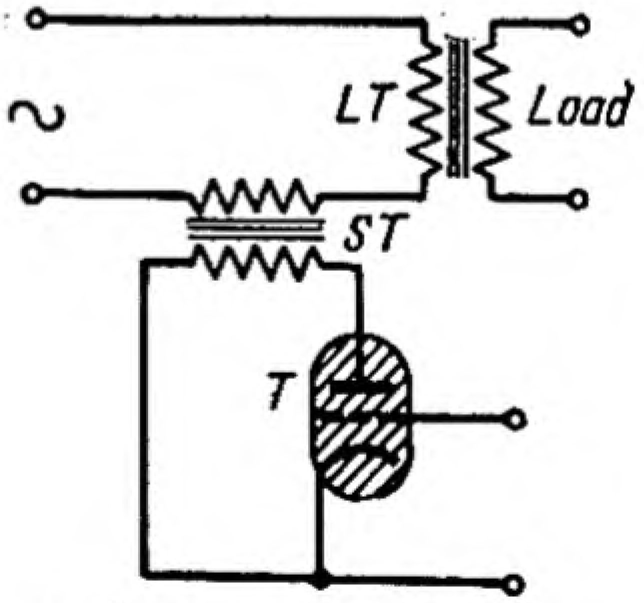


Fig. 325. Circuit using thyratron for control of current.

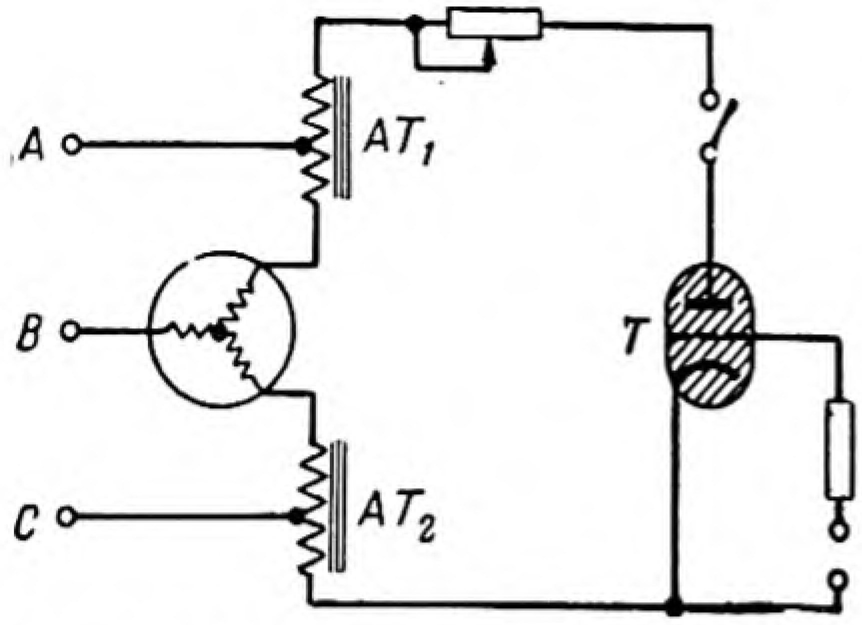


Fig. 326. Basic circuit of induction motor control by autotransformers and a thyratron.

Fig. 326 gives a basic circuit for three-phase induction motor speed control by series-connected autotransformers and a thyratron.

By controlling with the thyratron grid the current allowed to flow through autotransformers AT_1 and AT_2, wide-range control is obtained over the supply voltage applied to the motor and, consequently, over motor speed.

In addition to electronic control, modern electric drives are designed with rotary-machine control. The latter system is based on what is called a rotary-machine amplifier. Another form of control not discussed in this book is achieved with magnetic amplifiers.

The rotary-machine amplifier is actually a small d-c generator. Its basic circuit is represented in Fig. 327.

In this generator the frame carries an exciting winding EW for creating the field flux Φ_1. In addition to this main winding, the frame carries a compensating winding $Comp.W$ to balance out the armature-reaction field set up by load current I_3, and also a control winding CW which is connected into the circuit of the machine to be controlled by the amplifier.

The principle of operation of the rotary-machine amplifier can be explained as follows.

By energising exciting winding EW with small expenditure of power $P_1=U_1I_1$, the field flux Φ_1 is created. Since the armature rotates in this field, an e.m.f. E_2 is induced in the circuit of shorted brushes b_1, b_2. Notwithstanding its small value, E_2 is able to set up a large flow of current I_2 because of the extremely low resistance in the $b_1=b_2$ brush circuit.

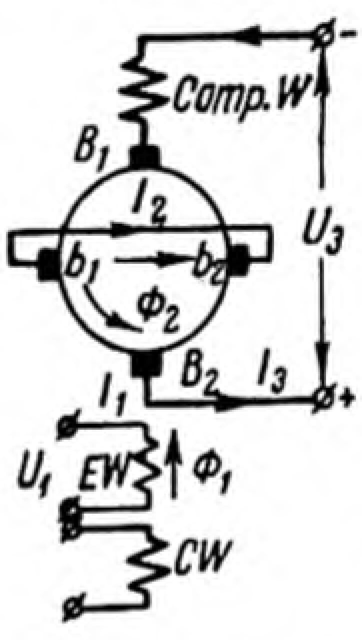


Fig. 327. Basic circuit of a rotary-machine amplifier.

Current I_2 then induces a relatively larger field flux Φ_2. This causes a considerable e.m.f. E_3 to be developed across brushes B_1 and B_2 and results in the flow of a relatively large load current I_3.

From what has been said above, it follows that power amplification takes place in two steps. First input power $P_1=U_1I_1$ is amplified to power $P_2=E_2I_2$. Then the latter, in turn, is amplified to output power $P_3=$ $=E_3I_3$.

The ratio

$$k_a = \frac{P_2}{P_1}$$

is called the amplification factor of the amplifier. In practice it reaches values near to 100, 000.

The above ability to provide high amplification, quite evidently, can be put to use for controlling electric drives with a very small input of control power. Furthermore, the requirement of only a small input makes it possible to use less costly control apparatus designed for handling small currents.

It is likewise possible, through changes in power input, to control within a wide range the speed of motors used to drive various kinds of machines.

At the present time rotary-machine amplifiers are extensively used in industrial works for automatic control of many kinds of electric drives.

One simplified basic circuit for control of a d-c generator with a rotary-machine amplifier is given in Fig. 328.

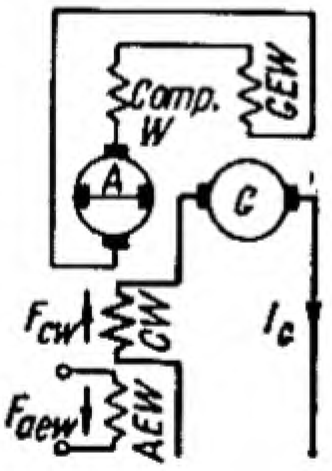


Fig. 328. Basic circuit for automatic control of d-c generator load current with a rotary-machine amplifier.

As seen from this circuit, the exciting winding *GEW* of the d-c generator is energised by rotary-machine amplifier *A*. The amplifier exciting winding *AEW* is fed from an independent source of supply.

Amplifier control winding *CW* is connected in series with the generator armature circuit so that the magnetomotive force F_{cw} which it creates opposes magnetomotive force F_{aew} set up by exciting winding *AEW*. The excitation field induced in the amplifier will then depend on the difference in the magnetomotive forces or $(F_{aew} - F_{cw})$.

If a change occurs in the generator armature current I_G, for example a rise in the current, the difference $(F_{aew} - F_{cw})$ becomes smaller because F_{cw} has increased.

Since the amplifier excitation field strength depends on the difference $F_{aew} - F_{cw}$, it must also decrease. This leads to a corresponding drop in generator voltage and, therefore, to lowering of generator current I_G.

We thus see that the above circuit automatically maintains the generator load current at a set level. This feature permits it to be used for automatic control of electric drives.

Task 1. Draw a full circuit diagram for control of a squirrel-cage induction motor from two different work stations with the use of a reversing magnetic starter.

Task 2. Complete the circuit diagram given in Fig. 321 and draw the full circuit diagram for control of two induction motors which must be started only one at a time.

Task 3. Complete the circuit diagram given in Fig. 322 and draw the full circuit diagram for control of two induction motors which require consecutive starting (first one and then the other).

Chapter XII

MOUNTING OF LOW-POWER ELECTRIC MOTORS

Low-power electric motors are generally mounted in one of the following ways: on timber or metalwork platforms placed on a floor, on concrete block foundations (Fig. 329*a*), on brackets fixed to a wall (Fig. 329*b*), or directly on the frames of the machines they operate.

Motors mounted on timber frameworks are fixed with lag screws driven after first drilling smaller-sized holes for them with a gimlet. To secure motors to metalwork, bolts are used.

Motors are fixed on concrete block foundations by grouting their anchor bolts into the concrete block.

When a motor weighs less than 80 kg, it can be lifted by hand for mounting at some height above floor level. Motors of heavier weight must be lifted and placed on their supports with the aid of a chain hoist or block and tackle (Fig. 330).

Regardless of the method used to mount a motor, it must be set with its shaft truly horizontal. This is checked by placing a spirit level on a straight edge laid on the motor slide rails or by means of a special shaft level. The latter has a longitudinal dovetail groove in its base to allow the level to be

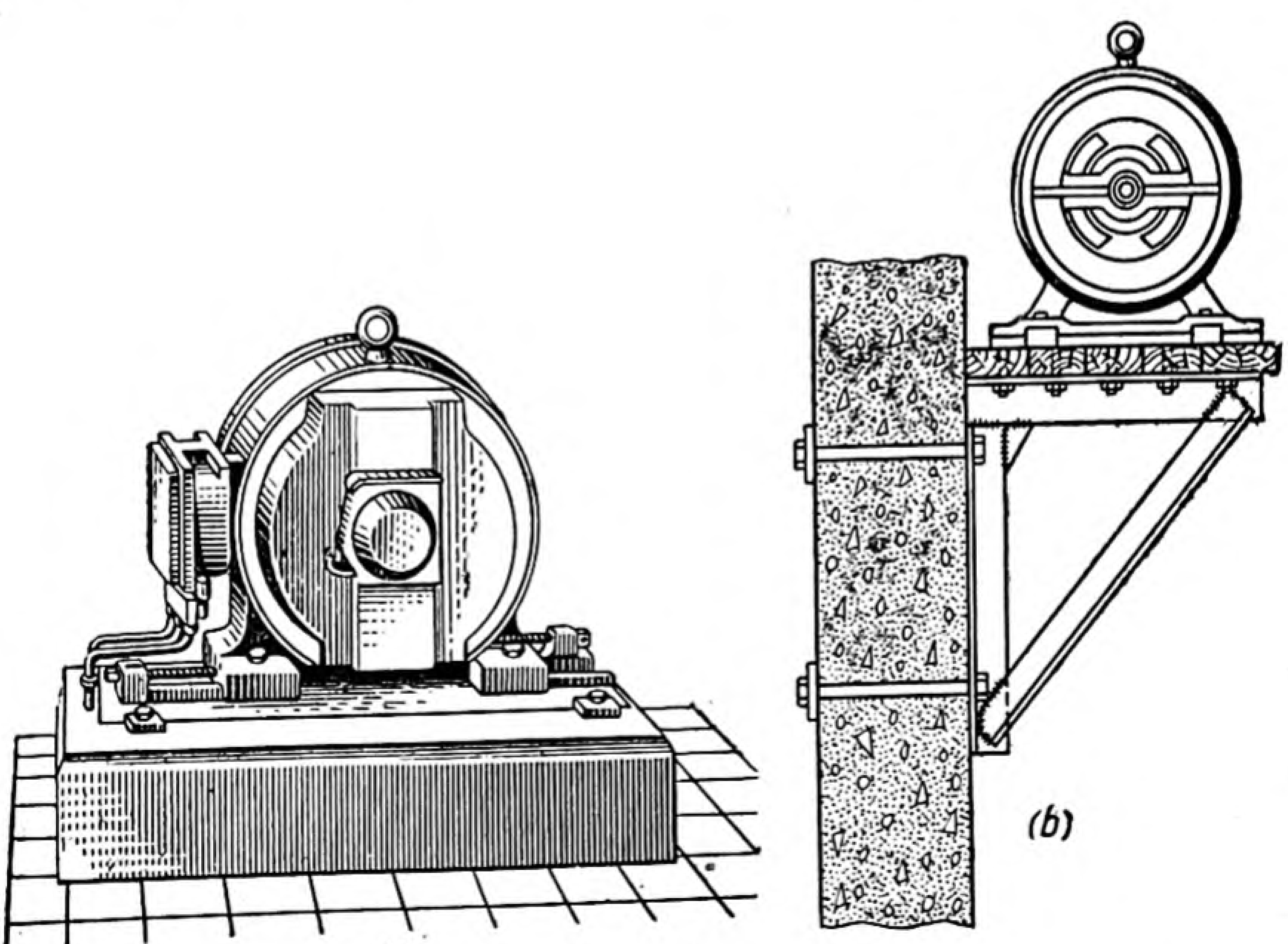


Fig. 329. Motor mounting:
a—on concrete block foundation, *b*—on a wall with the use of a bracket.

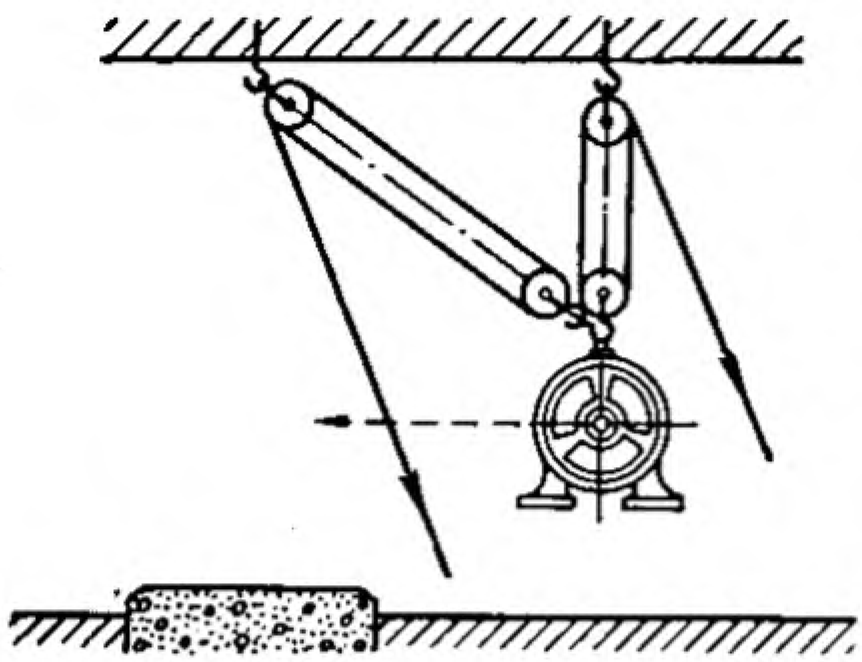


Fig. 330. Motor being raised for mounting with the use of block and tackle.

placed on the shaft when aligning.

In carrying out the levelling of a motor thin steel shims are inserted under its feet where needed.

Another alignment motors require is proper positioning with respect to the machine or element the motor is to drive. The method of checking for alignment depends on how the motor is to be connected to its associated drive.

If connection is to be accomplished with a belt drive, the motor shaft must be set parallel to the follower pulley shaft, and the motor pulley must be so aligned with the follower pulley that one axial line will pass through the middles of their rim faces. If the pulleys have rims of the same width, the shafts will be parallel when points *1*, *2*, *3* and *4* shown in Fig. 331 lie in one line. Practically, this is checked with a stretched string.

When the pulleys have rims of unequal width, the centre lines of the drive and follower pulley rims must be "dropped" to the floor by hanging two pairs of plumb bobs as shown in Fig. 332 and stretching an aligning string somewhat beyond the motor pulley position and also so that it passes under the pointed ends of the two plumb bobs dropped from the follower pulley. The motor can then be shifted into a position which brings the second pair of plumb bobs directly over the stretched string.

For greater accuracy the alignment should be repeated twice, each time shifting the plumb bobs on the pulleys to new positions to the left and right of pulley centres.

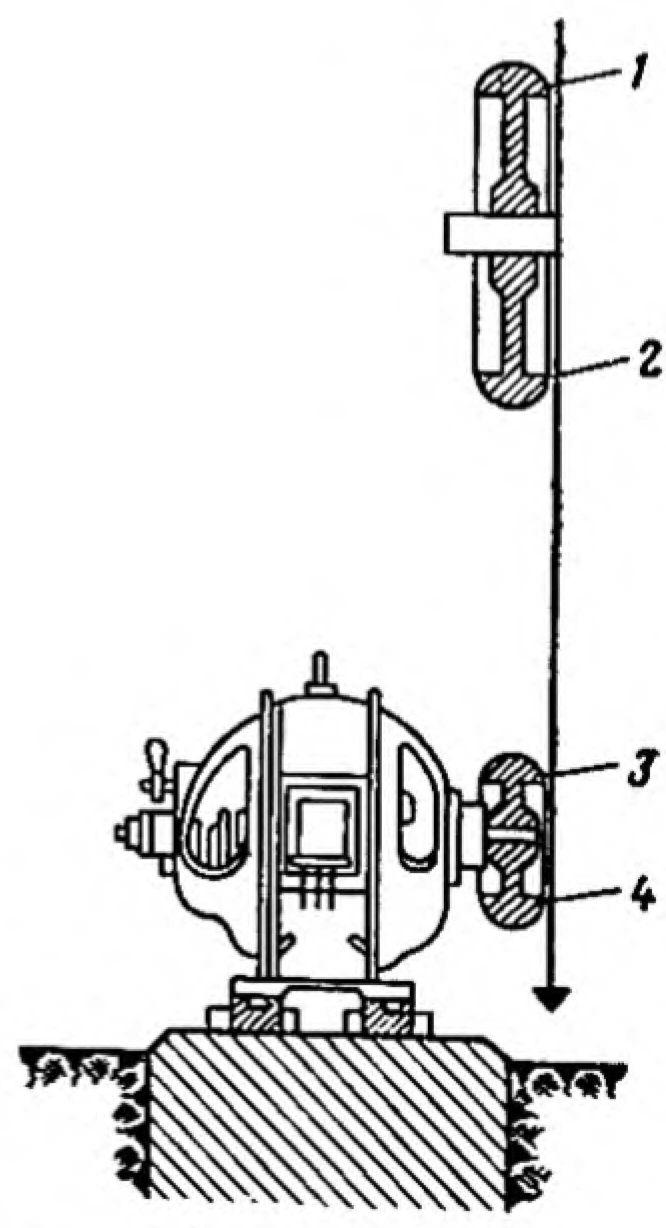


Fig. 331. Aligning motor shaft for parallelism with follower pulley shaft in belt drive when both pulleys have the same width.

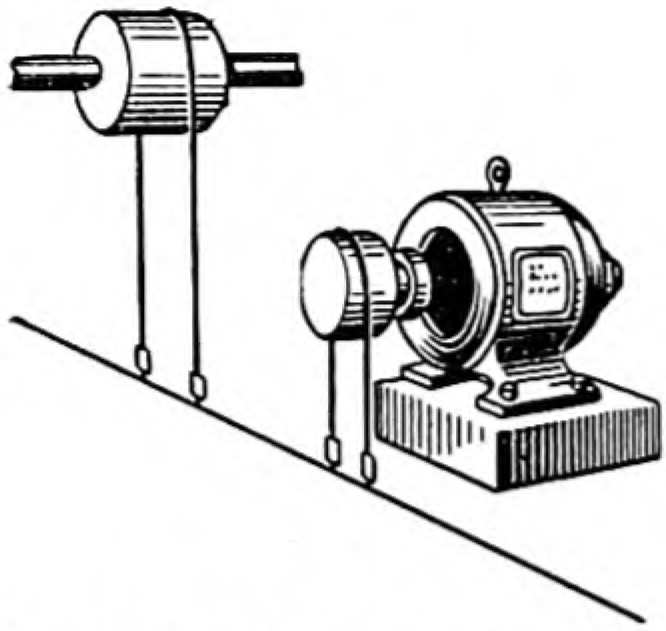


Fig. 332. Aligning motor shaft for parallelism with follower pulley shaft in belt drive when the width of pulleys differs.

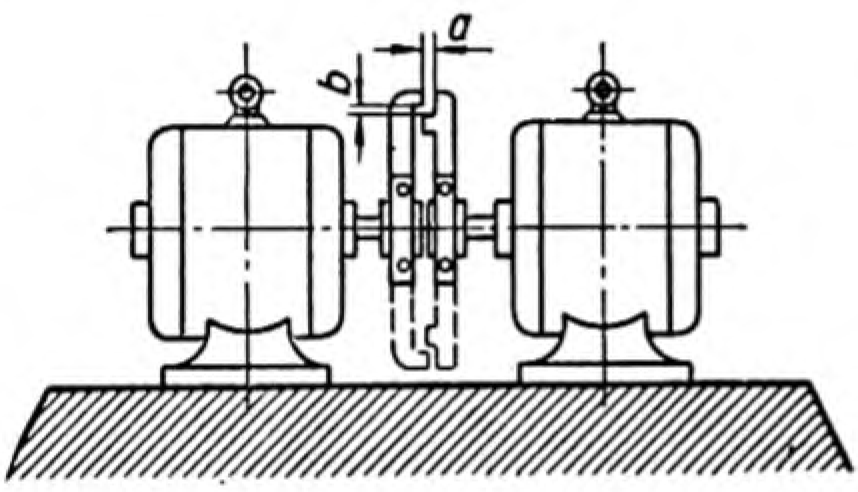


Fig. 333. Aligning of a rigidly coupled two-machine unit.

To carry out alignment of a motor to be connected to its drive with a rigid coupling consisting of two half-parts (Fig. 333), gauging bars are clamped on each of the half-parts. Two sharp edges are provided on both of the gauge bars: one horizontal, the other vertical. The aligning consists in so positioning the motor that when the shafts of both the motor and the drive are turned in the same direction gaps *a* and *b* between the sharp gauge edges remain unchanged.

Motors directly mounted on a machine (when connection with the drive shaft is made through direct spur reduction gearing) require that their shafts be properly aligned with the respective drive shafts. Both the motor and corresponding gear shaft must be strictly in parallel with each other. The gear teeth will then properly mesh.

The above requirement will be fulfilled by making the clearance with which the teeth mesh the same on both sides of a tooth pair. To measure and check the clearance, a feeler gauge is used.

In all the cases of motor alignment discussed above, the necessary change in position of the motor shafts is obtained by shifting the motors in the corresponding direction and inserting thin steel shims under their feet.

A method never to be used for attempting to bring shafts into alignment is scraping of the bearing shells.

Part Six

OPERATION AND MAINTENANCE OF ELECTRICAL EQUIPMENT

Chapter XIII

OPERATION AND MAINTENANCE OF ELECTRIC CIRCUITS AND EQUIPMENT

1. Main Features of Management of the Electrical Services in Industrial Undertakings

The fundamental problem faced in setting up a system of management for operating and servicing electrical equipment in any industrial works is to ensure:

1) continuous trouble-free operation of the equipment;

2) maximum effective use of the equipment;

3) economical operation;

4) smallest possible costs of operation;

5) safety from electric shock hazards.

Continuous trouble-free operation and maximum effective use of electrical equipment can be attained by proper care, scheduled preventive maintenance, general overhauls and also timely replacement of equipment which has become obsolete or does not answer the local operating conditions.

Economical operation of electrical equipment depends on keeping energy losses down, working out the most rational schedules of operation for the various units of production equipment, providing individual units with automatic controls, and also on total automating of production processes from start to finish.

Operating costs of electrical equipment can be kept low mainly by correctly organising the maintenance work and by rational expenditure of parts and materials.

Safety from electric shock hazards is, first of all, achieved by high-quality workmanship of installation, and strict observance of acting Regulations for the erection and operation of electrical installations.

2. Maintenance of Power Electrical Equipment

Everyday inspections, which, as a rule, should be carried out before the beginning and after the end of each shift, serve as the main factor in ensuring

trouble-free operation of the electrical equipment.

All parts of motors, especially their commutators, slip rings and brush riggings, require regular cleaning from dust and dirt. This work is done with dry wiping cloths and vacuum cleaner units.

Motors which have deposits of dirt on their internal parts must be dismantled and cleaned.

Each motor after cleaning must be checked for proper condition of its contact connections, in particular, the terminals at which connection to power supply is made. Any loosened or oxidised contacts, when discovered, must be thoroughly cleaned bright with a fine-cut file or fine-grain glass paper.

During inspections particular attention is to be paid to the condition of commutators and slip rings. Their surface must be smooth and polished, otherwise sparking is inevitable.

When necessary, commutators and slip rings can be ground and polished, or even have their surfaces restored by turning in a lathe. Grinding is done with a special wooden block to which the glass grinding paper is attached (Fig. 334*a*).

If the mica segments begin to project from between the copper commutator bars, they must be undercut with a special undercutting saw (Fig. 334*b*).

Sliding friction bearings require especially close attention when they operate at heavy duty or in adverse surroundings (for example, in dusty premises). Oil should be added to them every day or every other day, and be fully replaced up to five times per month. Under normal operating conditions, oil can be added once or twice a week, the complete replacements being made at intervals of two to three months. Ball and roller bearings should have their grease fillings renewed once every year.

The size of the air gap between the rotors and stators of electric motors requires systematic checking. This is done

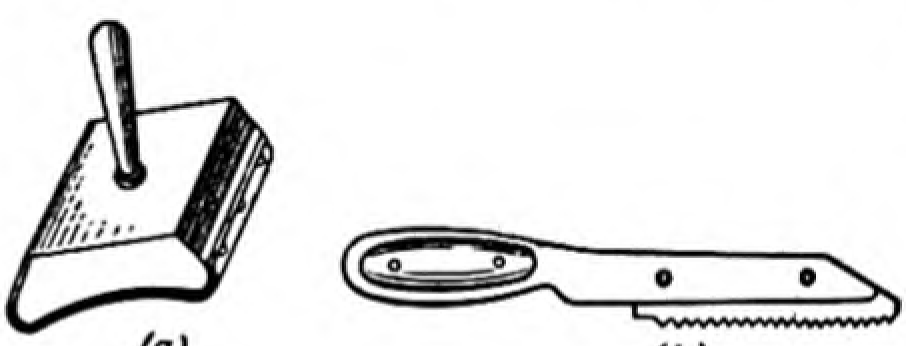


Fig. 334. Grinding paper block used to smooth commutators and slip rings and saw for undercutting commutator mica:
a—block with glass paper attached, *b*—saw.

with a feeler gauge at three to four points round the rotor. As soon as the gaps in a machine are found to differ, the bearing shells must be refitted or replaced.

The most probable of the troubles and defects encountered in motor operation are listed in Table 32.

Table 32

Common Troubles of Electric Motors and Methods of Remedy

Kind of motor	Trouble	Probable causes	Remedy
D-c motor	Motor fails to start	1. Fuses blown	Replace fuses
		2. Motor overloaded	Remove overload
		3. No contact between brushes and commutator	Bed brushes for proper fitting
		4. Improper connection of leads to rheostat	Check connections and properly reconnect them
		5. Open circuit in armature winding	Repair motor
	Fuses blow when motor is switched on	1. Motor started with starting rheostat shorted out	Check the rheostat
		2. Notching of rheostat from position to position at too high speed	Notch rheostat at slower speed during start
		3. Fault in control devices	Check control devices
		4. Start was initiated from running and not from starting position of control devices	Check and return control devices to starting position
	Sparking at brushes	1. Motor overloaded	Remove overload
		2. Dirty or blackened commutator	Clean and grind commutator
		3. Brushes in bad condition or of wrong grade	Replace brushes
		4. Mica segments protrude on commutator	Undercut mica on commutator
	Armature winding overheats	1. Motor overloaded	Remove overload
		2. Worsened conditions of cooling	See that motor has not lost its necessary speed

Kind of motor	Trouble	Probable causes	Remedy
	Overheating of commutator and brushes	1. Excessive brush pressure	Adjust pressure to required value
		2. Brushes too hard	Replace brushes
		3. Poor contact in brush rigging connection	Remedy bad contact connection
A-c induction motor	Motor fails to start	1. Fuses blown	Replace fuses
		2. Wrong connection of start and finish of phase windings	Check and correctly reconnect windings
		3. Motor overloaded	Remove overload
	Motor runs at abnormal speed	1. Motor overloaded	Remove overload
		2. Stator winding is star-connected instead of being delta-connected	Reconnect stator winding
		3. Poor contact in rotor circuit	Check and repair fault in rotor short-circuiting device
	Overheating of stator winding	1. Overload	Remove overload
		2. Worsened conditions of cooling	Restore normal conditions of cooling
		3. Stator delta-connected instead of being star-connected	Check and reconnect stator windings
	Overheating of rotor winding	1. Overload	Remove overload
		2. Rotor rubs against stator	Adjust air gap, replace bearing shells

When motor starting and speed control apparatus is inspected, the permanent-connection contacts should be very thoroughly examined; also to be examined are the switching contacts, electromagnets and mechanical parts.

If the apparatus is dirty or dusty, it must be cleaned. Loosened contacts should be tightened. Where contacts are oxidised or burnt, they must be thoroughly cleaned bright.

3. Preventive Maintenance of Power Electrical Equipment

Electrical equipment should be inspected without dismantling at fixed, short, but regular, intervals of time according to an approved routine inspection schedule. During routine inspections the actual condition of the equipment is determined, the accessible parts are cleaned, small short-life components are replaced, and, in cases when repair is found to be necessary, a date is set for taking the equipment out for a maintenance repair. Preventive maintenance is carried out on a schedule having greater intervals of time. The work consists in cleaning, examination and dismantling of electric motors, replacement of worn parts and adjustment of certain assemblies.

When necessary, defective equipment is taken out for a general overhaul. To accomplish a preventive maintenance repair in the shortest possible time, the necessary quantity of spare parts and associated accessories must always be kept in supply. The storeroom keeper should see to it that the quantity on hand accords with an authorised stock list.

The intervals at which the preventive maintenance repairs are timed depend entirely on the conditions under which the equipment operates and on the nature of the load it carries. For example, electrical equipment has to operate in shops where the atmospheres are dusty or clean, moisture- or vapour-laden, or in which the ambient air temperature is either high or low.

To draw up a schedule for preventive maintenance, reference is made to approved or recommended standards of periodicity (Table 33 p. 290).

The work operations which are included in the scheduled routine inspections and the preventive maintenance repairs are listed in Tables 34 and 35 (see pp. 291-294).

The operations given in the above-mentioned tables do not cover all types of motors and their starter and speed-control apparatus. It is therefore necessary to add or correct these lists in keeping with local requirements.

The results of the routine inspections can be recorded in a special motor-inspection record book; those of large and high-voltage motors (beginning with a rating of 100 kw), in special record file sheets.

Table 33

Preventive Maintenance Scheduling Intervals for Electric Motors and Their Starting and Speed Control Apparatus

Kind of shop	Schedule interval for open motors	Notes
Machine shops containing a small number of grinding machines	Once a year	—
Machine shops containing grinding machines doing over 10 per cent of the work on cast iron parts or over 20 per cent of the work on steel parts	Four times per year	For enclosed motors — twice a year
Cold-stamping shops	Once a year	—
Forge shops, rolling mills, wire-drawing departments	Twice a year	For enclosed motors — once a year
Foundry shops	Four times a year	For enclosed motors — once a year
Cabinet-making shops, sawing mills, wood-working shops	Four to five times a year, depending on conditions of ventilation	For enclosed motors — once a year
Shops with a dust-laden atmosphere	As above	As above
Shops with a moisture-laden atmosphere	Four times a year	—
Sheps in which acids are used	Four times a year	Motors must have acid-resistant insulation or be of totally enclosed type

Table 34

Routine Inspection Operations

Kind of motor	Operation	Nature of work
Induction motor *	Cleaning without disassembly	1. Cleaning of slip rings and brush-holders
		2. Cleaning of windings and blow-out of ventilating passage at accessible places
		3. Cleaning of external surfaces of frame
	Inspection of bolted connections and tightening of nuts	1. Inspection of foundation bolts
		2. Inspection of endshield bolts
		3. Inspection of bearing-housing cover bolts
		4. Inspection of bolts, screws and nuts of brush-lifting mechanism
		5. Inspection of earthing
	Checking coupling and drive parts	1. Checking for tight fit of pulley and tightness of bolts on coupling
		2. Checking for wear in gearing and their replacement (if necessary)
	Inspection and checking of brush-holders and brushes	1. Adjusting brush pressure
		2. Replacing highly worn brushes
		3. Bedding of brushes
		4. Adjusting brush-holders (distance between brush-holders and surface of slip rings)
	Inspection of bearings	1. Checking for normal turning of the oil rings in the bearing
		2. Checking the size of the clearance in the bearings
		3 Checking for noise or overheating in the bearings

* When inspecting a squirrel-cage induction motor, disregard operations having to do with wound rotors.

Kind of motor	Operation	Nature of work
	Inspection and cleaning of contact connections at motor terminals	1. Checking for overheating
		2. Replacement of lugs on conductors (when necessary)
		3. Tightening terminal screw nuts
	Inspection and cleaning of rheostat	1. External cleaning of rheostat
		2. Cleaning of rheostat contacts (when necessary), their replacement
		3. Replacing damaged resistor sections
		4. Adding oil
		5. Checking of earthing
	Inspection and cleaning of starting apparatus	1. Cleaning of apparatus without disassembly
		2. Cleaning of contacts and their replacement whenever necessary
		3. Replacing damaged parts
		4. Checking of earthing
D-c motor	Cleaning and examination of motor and its starting apparatus without disassembly	All the general work operations carried out on a-c induction motors (stated above) also apply to d-c motors
		Particular care is taken in:
		1 Inspecting and cleaning commutator
		2. Checking brush pressure
		3. Replacing worn brushes
		4. Bedding of brushes
		5. Adjusting brush-holders

Preventive Maintenance Repair Operations

Kind of motor	Operation	Nature of work
Induction motor *	Checks prior to dismantling	1 Measuring air gap between stator and rotor 2. Measuring clearances in bearings 3. Determining insulation resistance
	Cleaning and dismantling	1. Blowing out ventilating passages 2. Cleaning and varnish coating of windings 3. Washing of bearings 4. Cleaning slip rings and brush-holders 5. Cleaning terminal block 6. Cleaning drive parts (couplings, gearing, pulleys, etc.)
	Replacement and repair of damaged and worn parts	1. Re-babbiting or replacement of bearing shells, replacement of worn ball and roller bearings 2. Replacement and repair of defective brush-holder parts and brush-lifting mechanism 3. Replacement of worn brushes 4. Correction of damaged places in air ducts (of ventilated motors) 5. Turning of rotor slip rings in a lathe (if required) 6. Replacement of worn and damaged drive parts (gears, coupling parts, etc.) 7. Replacement of bad cable lugs on supply cable conductors
	Assembly of motor and its alignment on the foundation or support platform	1. Checking drive parts for tight fit (couplings, pulleys and other components) 2. Alignment of motor on its foundation or support 3. Checking and tightening bolted joints 4. Check for presence and proper size of air gap between rotor and stator
	Adjusting brush-holders and brushes	1. Adjusting brush pressure 2. Bedding of brushes 3. Adjusting for proper distance from brush-holders to slip rings
	Checking of earthing	Checking and repair of earthing strip or conductor
	Inspection, cleaning and repair of rheostat	1. Dismantling and cleaning of rheostat 2. Purification or replacement of oil 3. Cleaning and (when needed) replacement of contacts

* When servicing a squirrel-cage induction motor, disregard operations having to do with wound rotors.

Kind of motor	Operation	Nature of work
		4. Replacement of damaged resistor elements
		5. Checking and repair of the earthing connection
	Inspection, cleaning and adjustment of starting apparatus	1. Cleaning of apparatus (dismantle when required)
		2. Cleaning contacts of oxide film and tightening
		3. Cleaning and (if needed) replacement of contact plates
		4. Adjusting pressure on contacts
		5. Checking and repair of earthing connection
		6. Repair or replacement of faulty parts in operating mechanism
	Checking and resetting of protective devices	1. Checking for required current rating of fuses
		2. Checking for proper rating of heating element in thermal relay
	After-repair checking	1. Insulation testing
		2. Load testing of motor, rheostat and starting apparatus
D-c motor	Checks prior to dismantling	Same as for induction motor
	Cleaning and dismantling	Same as for induction motor, but, in place of slip rings, commutator is cleaned
	Replacement and repair of worn parts	Same as for induction motor; instead of turning slip rings, turning of commutator in a lathe
	Assembly and alignment of motor	Same as for induction motor
	Adjusting brush-holders	Same as for induction motor
	Checking of earthing	Same as for induction motor
	Inspection, cleaning and repair of rheostat	As for induction motor
	Inspection, cleaning and repair of starting apparatus	As for induction motor
	Checking protective devices	As for induction motor
	After-repair checking	As for induction motor

4. Preventive Maintenance of Shop Switchgear Installations, Electric Circuits and Lighting Systems

Power and lighting circuits in industrial shops require, to the same degree as electric apparatus and motors, systematic inspection and scheduled preventive maintenance. Failure to keep watch over the electric circuits and maintain them in fit condition results in such deterioration that the costs due to current leakage become rather high. In addition, a direct fire hazard is created.

The operations and jobs which make up a shop circuit preventive maintenance programme are very wide in nature, many in number, and, in the majority of cases, dependent on the particular operating conditions existing in a given works. The main elements going to make up the preventive maintenance programme are those discussed below.

Preventive Maintenance of Shop Switchgear Installations. Of vital importance for the continuous, trouble-free operation of shop switchgear installations is the condition of their contacting parts. A contact connection which is defective and, consequently, is nearly always overheated, leads to burning of the bus-bars or conductors it joins and ends in breakdown and outage of the switchgear. During routine inspections of switchgear installations the overheating of contact connections, especially in bus-bars of large size, can be detected by looking for the temper colours which appear on the bars in such cases. In addition, if the end of a paraffin or special temperature-detecting candle made from a compound with a low melting point is pressed against an overheated contact, the overheating is revealed by melting of the candle.

When such candles are used in installations with a voltage up to 500 v, the man doing the checking must wear rubber gloves and have rubbers on his shoes.

If the working voltage in the installation exceeds 500 volts, the candle is to be attached to an insulating rod, and the checker must wear dielectric rubber gloves.

A much better method is to quickly remove the voltage from the installation after it has been under load for three to four hours and then check the contact connections by feeling them with the hands. This method, however, has limited possibility for use because it requires an interruption in power supply.

The most rational method for revealing overheating in contact connections is to use colour indicating thermofilms (see Table 31).

Also included in the preventive maintenance schedule are such operations as: checking fuses for circuit continuity, removing dust and dirt from the parts in the switchgear installation, cleaning of make-break contacts and checking them for adequate contact pressure and

fit, removing oxide from permanent contact surfaces and tightening of their jointing bolts, examination of insulators for complete intactness, replacement of insulators wherever necessary, and checking and repair of the earthing conductor system.

Preventive Maintenance of Shop Electric Circuits. When the wiring in a shop is checked, attention is paid to the tightness of open-run wires. If they have excessive sag, they are either further tensioned or completely retensioned. Places which require close examination are those where wires enter and come out of wall and floor structure openings, and where wires drop into and rise out of undersurface runs. In cases of necessity, the insulating bushings, porcelain bent tubes and insulating tubing are replaced. The condition of the insulation is also checked by external examination. Sections within which the insulation has been injured are completely rewired. Where needed, the knob insulators, cleats and other accessories are replaced. The condition of the shop circuit insulation is tested for adequate dielectric strength by measuring the insulation resistance with a megohmmeter.

The general view of a megohmmeter, its basic circuit and the external connections for testing a circuit are given in Fig. 335.

The instrument is used with two leads, one for connection to the circuit under test (Fig. 335*c*), the other for connecting earthing terminal E to earth. To obtain a reading, button B is held down and the operating handle is rotated at a speed which brings the voltage across the instrument terminals up to the working voltage of the circuit under test. With the handle still rotated at the same speed, the button is next released and a reading taken from the scale. The instrument pointer will give

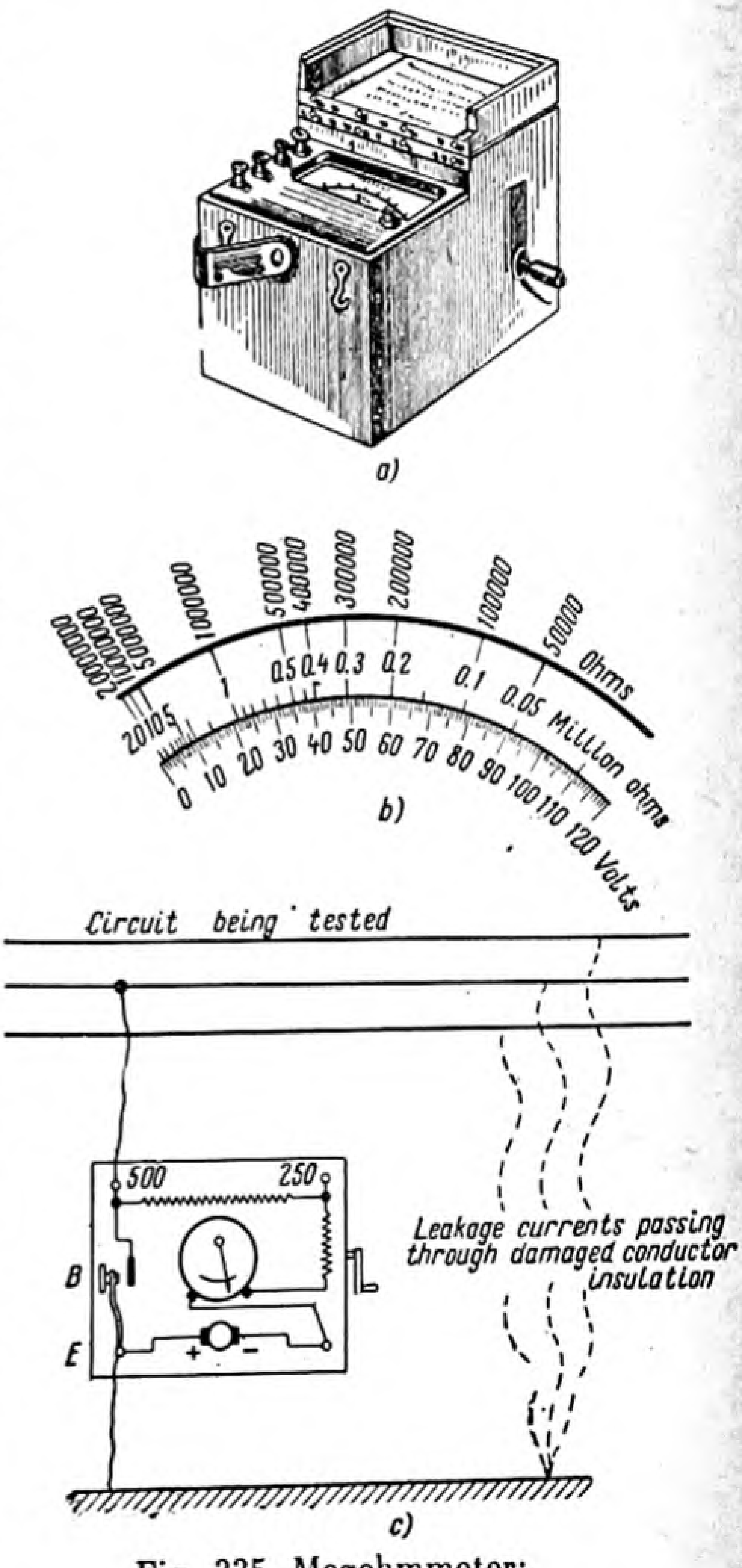


Fig. 335. Megohmmeter:

a—general view, *b*—megohmmeter scale, *c*—internal circuit connections and leaps connected to a circuit and earth for testing.

the reading in ohms or megohms of insulation resistance.

When the readings given by the megohmmeter show that the insulation resistance is below standard (1,000 ohms per each volt of rating), it means that the insulation in the circuit under test has been damaged and the defect must be searched out and remedied.

Together with the measurement of the insulation resistance, an inspection of the earthing connections and of the entire earthing circuit is carried out. All defects should be immediately remedied.

Note: The resistance to earth of the earthing electrodes is to be checked by a testman from the work's laboratory. The total resistance to earth of an earthing-electrode circuit should not exceed 4 ohms.

Repair and Cleaning of Lighting Fittings and Control Devices. Lighting fittings must be checked for the reliability of their fixings, the condition of the lamp holders and the condition of their separate parts. Lighting-circuit control devices are also checked for the reliability of their fixings, the condition of their parts and their intactness as a whole (lighting switches, plug sockets).

Lighting fittings, especially those with powerful lamps, are checked for their ventilation. Any hindrance to their ventilation leads to shortening of lamp life and loss of the seal between the bulb and the base shell.

Lamps which have darkened bulbs due to deposits which have appeared on the inside must be

Table 36

Intervals Between Repairs and Cleaning for Shop Indoor Circuits

Name of work	Schedule interval
Preventive maintenance of low-voltage switchgear and switchboards	Not less than once a year
Cleaning of low-voltage switchgear and switchboards	One to six times a year, depending on local conditions
Preventive maintenance of shop cable circuits	At least once a year
Preventive maintenance of shop outdoor circuits	At least twice a year
Checking of earthing system	At least once a year
Preventive maintenance of lighting fittings	At least twice a year
Insulation resistance testing of circuits	At least once a year
Cleaning of lighting fittings and lamps:	
a) in premises where much dust, smoke and soot are created	Four times a month
b) in premises with small quantities of dust, smoke and soot in the air	Once a month
Checking of stationary lighting circuit equipment	Once every two months
Checking for burnt-out lamps in all the premises and at all work places	Once a day

replaced; they are unable to furnish the required light flux. Each lighting fitting, as a whole, and its reflecting surfaces in particular, require a thorough wiping to clean off all the dirt and dust.

To select a repair and cleaning schedule for shop indoor circuits, the data listed in Table 36 can be used for guidance.

Task 1. When a certain shunt-wound d-c motor is switched on by its starter, it fails to start.

State what probable causes prevent it from starting and what measures must be taken to find and remedy them.

Task 2. During the operation of a squirrel-cage induction motor it is found that its stator winding has become overheated. The motor operates without any overload, its ventilation is normal and the motor windings are connected as shown in Fig. 336. The supply voltage is 380 volts and the motor voltage rating given on the name plate is U=380/220 v.

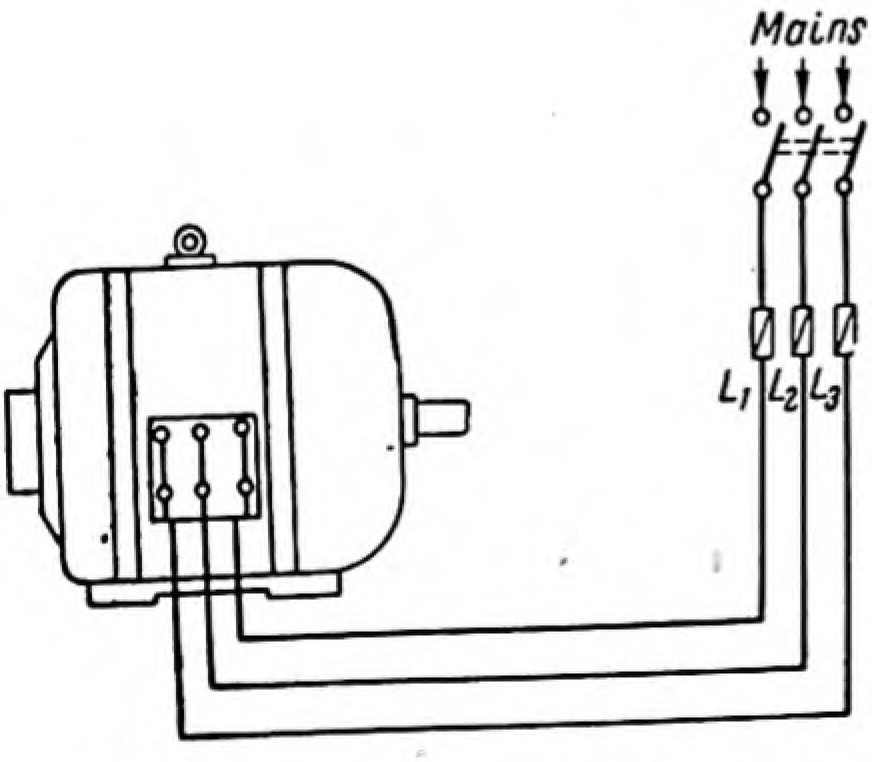


Fig. 336. Connections of motor.

State the probable cause of overheating of the stator winding and what should be done to eliminate the overheating.

5. Main Elements of Power Cable Line Operation

Care of Cable Lines. One of the fundamental requirements of cable line operation is to keep watch over conditions existing along the cable route and watch over the condition of the cable proper. This will ensure safe keeping, and prevent injury and development of adverse operating conditions.

Watch over cable lines mainly consists in regular patrolling of the cable routes and inspection of the cables.

During the inspections, open-run cables are checked for intactness of their protective sheaths, proper condition of the joint boxes, post installation tensioning and shifting, excessive sag and disturbed spacing between each other (spacings must conform with standard requirements).

Operating cable circuits must be checked from time to time to know the magnitude of their load currents and to keep their operating temperature under control. In connection with this, each cable line is assigned a permissible load current selected in accordance with the temperature rise for which its cores have been rated.

The permissible continuous load currents for cable lines depend upon the current density in the cores (Table 37).

Table 37

Permissible Continuous Current Densities for Cable Lines

Number of hours maximum load is carried per year	Current density for copper core cables, a/mm²
Up to 1,000 inclusive	Not checked
1,000 to 3,000 inclusive	2.5
3,000 to 5,000 inclusive	2.5
over 5,000	2.0

Cable lines may be allowed to carry an overload for not more than 2 hours and only in cases of emergency. When rated for voltages up to 3 kv, cables may carry an overload of 10 per cent; when rated for 6 and 10 kv, they may carry an overload of 15 per cent.

According to the U.S.S.R. State Standard cable conductors may have a maximum permissible temperature of:

for cables rated up to 3 kv...80°C
for 6-kv cables...65°C
for 10-kv cables...60°C.

Control over the loads is carried out by watching the indications of the switchboard ammeters. The readings of the ammeters are recorded by the duty attendant in the daily log sheet at intervals required by local acting rules.

Each switchboard ammeter used to indicate the current of a given cable line should have a red line marked on its scale at the maximum permissible continuous load current the cable can be allowed to carry.

In unattended substations the loads are checked at regular intervals by measurements taken with the aid of portable ammeters (generally of the clip-on type). Such measurements should be made at least two to three times each year, with one to two of the measurements taken during the autumn-winter peak load period.

The temperatures of the metallic sheaths of cables are watched by measuring them with a thermometer attached to the outer surface of the cable sheath when the cables are openly installed in tunnels, in accessible cable raceways, in riser shafts, etc. If the cables are buried in earth or run in inaccessible places, the sheath temperatures are measured by means of thermocouples attached to the metallic sheaths.

Preventive Maintenance Testing of Cable Lines. To guard against breakdowns of the cable insulation, cable joints and end

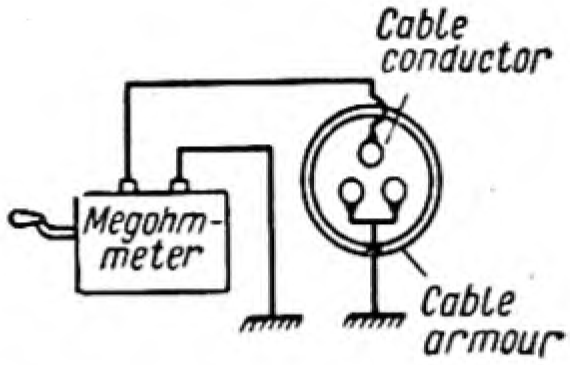


Fig. 337. Connections for testing a cable with a megohmmeter.

seals during the service life of cable lines, periodic preventive maintenance tests must be conducted.

During the above tests measurements are taken of the insulation resistance of each cable conductor with respect to all other conductors, as well as to the sheath. An inspection of the sealing ends, and also of the support insulators up to the cable isolator or disconnecting device, is also carried out at this time.

The preventive maintenance testing of power cables is performed with:

a) a high-voltage megohmmeter having a voltage of 1,000 to 2,500 volts;

b) a high-voltage d-c potential, a measurement of the leakage current being taken at the same time.

Checking with a 1,000-2,500 volt megohmmeter (Fig. 337) is done to detect noticeable defects in the insulation, breaks in the conductors and earthing of a phase. This is a routine check test which is performed before permitting switch-in of a cable for operation.

The main preventive maintenance testing method for cables is that of high-voltage cable line testing with a d-c potential which serves to reveal the local concentrated points of breakdown which a megohmmeter is unable to detect.

High-voltage d-c testing is performed with a kenotron rectifier unit to obtain a breakdown to earth in the cable at the local points of defect in the insulation. One of the most widely used kenotron units is the АКИ-50 (AKI-50) cable testing set. It is designed for 127/220 volt single-phase 50-cycle supply and has a power requirement of 0.5 kva. A general view of this set is given in Fig. 338.

Note: The operation of this set and its circuit requires special study of the operating instructions furnished with each set.

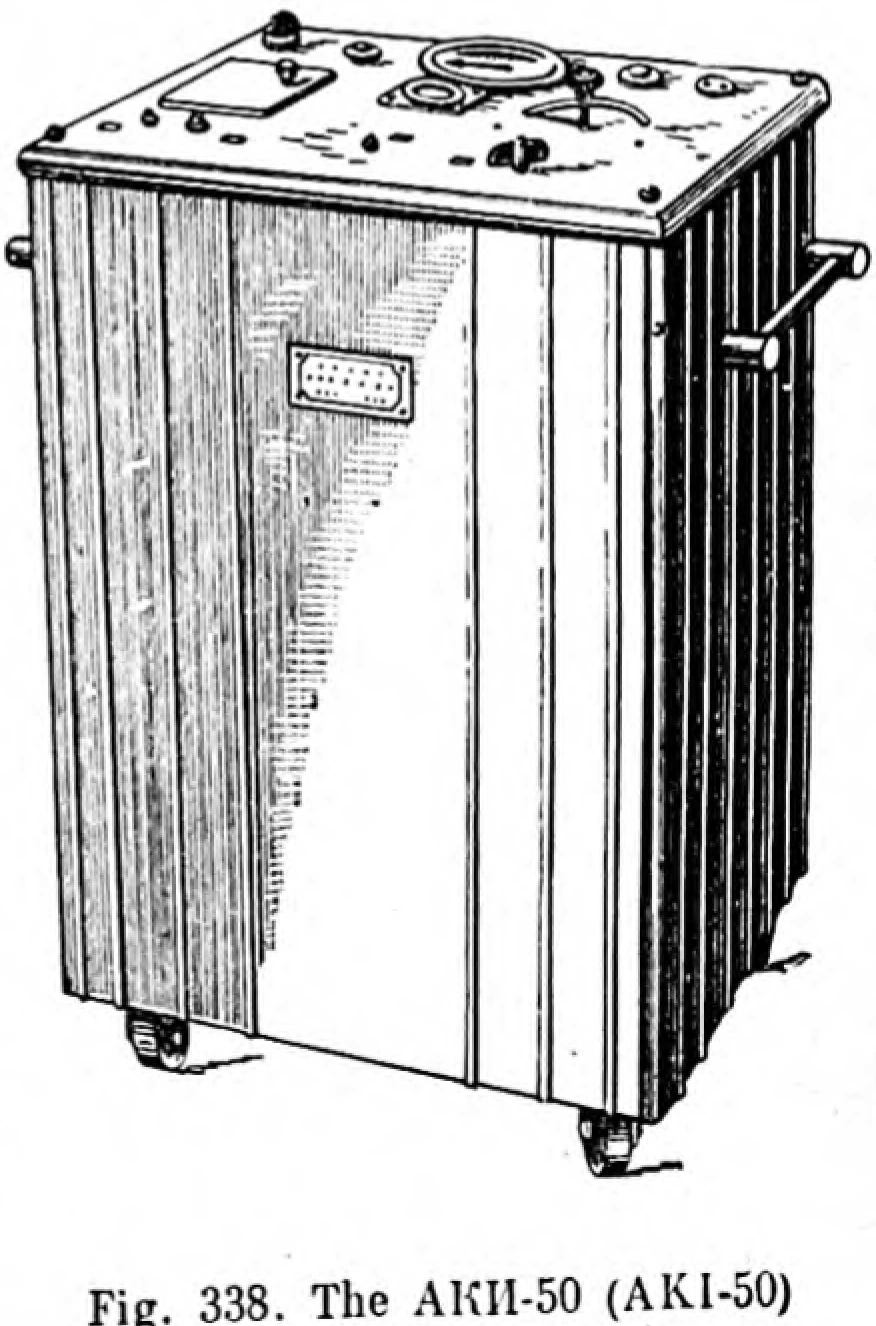


Fig. 338. The АКИ-50 (AKI-50) high-voltage test set.

6. Overhead Power Line Maintenance

Overhead power lines, due to the fact that they are continuously under the action of the atmosphere, are very liable to damage.

Sharp changes in temperature, in wind speed, rain, snow and dust, and discharges of lightning are all factors which have a destructive effect on the various elements of overhead transmission lines.

Overhead line maintenance consists, in the main, in preventing the development of faults, and in timely detection and remedy of defects by carrying out regular inspections (patrolling) of the lines when they are operating under voltage.

Damage and defects discovered during a patrol inspection, depending on their nature and line operating conditions, are remedied either immediately, or after special preparation and de-energising of the line.

When low-voltage overhead power lines are patrolled, the things to be watched for are:

1) possible breaks in the line wires and broken strands in the outer lays of multi-strand line wires;

2) foreign objects hanging from the line wires (pieces of wire, strings, threads, etc.) and contacting of line wires with adjacent buildings or other structures;

3) reliable contact connections between wires;

4) possible breaks in the tie-wires used to secure the line wires to the insulator heads;

5) intactness of the insulators and tight fitting of the insulators on their hook brackets;

6) amount of dirt on the insulators;

7) verticality of the line poles;

8) tightness of the guy wires and adequate strength of their fastenings at the poles;

9) intactness and full fitness of the wire bandings which secure stub poles to their line-support poles;

10) degree to which rot has attacked poles at ground line;

11) presence of ice on the line wires.

Practically all the above inspections are carried out by the patrol lineman. A very good aid in this work is a field glass.

The depth to which rot has attacked a pole is checked with a steel rod slightly pointed at one end. By sticking the sharpened end of the rod into the pole at three or four places round the circumference near ground level, the average depth of decay can be determined. When a pole has decayed to a depth of one-fourth its radius, it is considered no longer fit for service and is either completely replaced or fitted with a stub pole.

Close examination of line insulators, their cleaning, and replacement of the line conductor tie-wires are performed by a lineman (wearing climbing irons) when working on the pole. This work can be done only after the line has been de-energised.

During service, conditions may arise which make it necessary

to resort to emergency repairs. As a rule, such work must be done with the voltage removed.

7. *Operation and Maintenance of High-Voltage Electrical Equipment*

General. In industrial works substations the operation of the high-voltage equipment is under the supervision of the duty attendant. His main job is to see that the substation equipment is kept in fully safe and trouble-free operation.

During his shift the duty attendant makes regular rounds of the switchgear and other equipment; whenever necessary he performs the operative switching required for accomplishing a needed circuit arrangement change.

Order of Changing Shifts. In going on shift to relieve the man going off duty, the next substation attendant must make a round of all the equipment, check the safety aid accessories, the fire-fighting devices, tools, emergency materials and duty log books. He must make sure that the oil in the oil-filled apparatus is up to level, that the support insulators have not become chipped, have not cracked and are not dirty, that the contact connections do not show signs of overheating, and that the earthing buses and connections are in proper condition.

In addition, the man going on duty is obliged to see that the protective guards and cell barriers are intact and in position, that the various cell door locks are in fit condition and that the general and emergency lighting systems are in order.

The duty of the attendant going off shift is to point out all the units of equipment which require special attention, and also state which of the units are ready for stand-by service and which of the units have been taken out for repair.

All the shortcomings detected during the taking-on procedure must be entered in the duty attendant's log book.

Inspections. In making his regular rounds of the installation, the attendant must be on the look for defects in the various parts of the apparatus and equipment, watch for oil leaks in oil-filled apparatus, and also watch the contact connections for appearance of any signs of overheating. These inspections must be carried out at a guard rail or at the door opening of a cell. Under no conditions may a guard rail be removed or a cell entered if the equipment is alive.

No repair work must be done in the switchgear installation during an inspection round.

Operative Switching. Any operative changes in the circuit arrangements of a high-voltage switchgear installation are made only on presentation of written orders entered on a special signed blank.

Attendants have the right to disconnect the necessary circuit and equipment whenever

emergencies arise (a fire, accident, natural calamity), but must also immediately inform the duty engineer before whom they are responsible of the measures they have taken.

Operative switching must be carried out by the attendant with use of the corresponding prescribed safety accessories: the rubber gloves, rubber half-boots, insulating mats and floor platforms, and hook sticks.

Before the rubber gloves can be used, they should be checked to make sure that the rubber is not cracked, cut or punctured. For this, each glove is tightly rolled up from the open end towards the fingers (as shown in Fig. 339) to see that the trapped air does not escape.

Fig. 339. Dielectric rubber safety gloves.

Rubber gloves must be worn so that they cover the ends of the working jacket sleeves.

Rubber half-boots must also be inspected prior to use. They must be free from cracks, cuts and punctures.

When using a hook stick for operative switching, the stick must never be grasped by the hands higher than the guard ring provided at the top end of the handle section.

In carrying out an operative circuit change it is necessary to be constantly on the alert to follow correctly the sequence prescribed for switching of the particular circuit breaker and its associated isolators.

For example, let it be assumed that we have to disconnect the feeder connection shown in Fig. 340. The switch-out is performed in the following order: open circuit breaker *1*, then open line isolator *2* and complete the operation by opening bus isolator *3*.

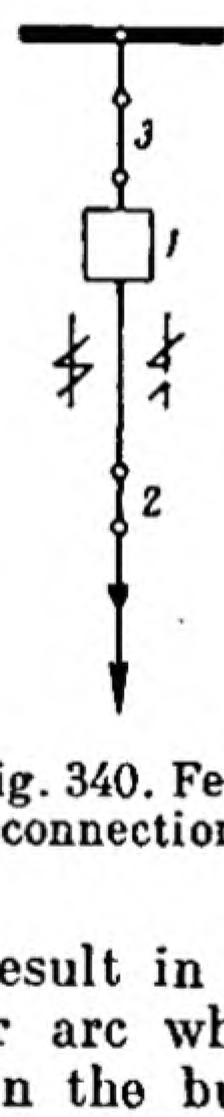


Fig. 340. Feeder connections.

The above order is governed by the fact that, if an attempt is made to begin disconnection by opening the bus insulator, this will result in appearance of a power arc which will create a fault on the buses and cause the entire installation to be switched off from supply.

When the same feeder must be switched in, the operation is performed in reverse order (refer to Fig. 340).

In this case the order is such that even if the circuit breaker has been closed and the line isolator is then thrown into its closed position, the arc will

appear across the contacts of the line isolator and not where it would be able to directly fault the buses.

Performance of Work in Live High-Voltage Installations. Work within the high-voltage installations of industrial works is performed with:

1) the installation completely de-energised;

2) the installation partially de-energised;

3) the installation left energised (hot).

To do any work within high-voltage installations, a special work order is required. It serves as the signed permission to perform a specified job or number of jobs.

The duty of the shift attendant is to prepare the installation for complete safety during performance of the work. That is, he must completely remove the voltage from the live parts on which the work is to be done, and must also block off all places where live parts at voltages up to 10 kv are within 35 cm, and where live parts at a voltage of 35 kv are within 60 cm from the place at which the work is to be carried out.

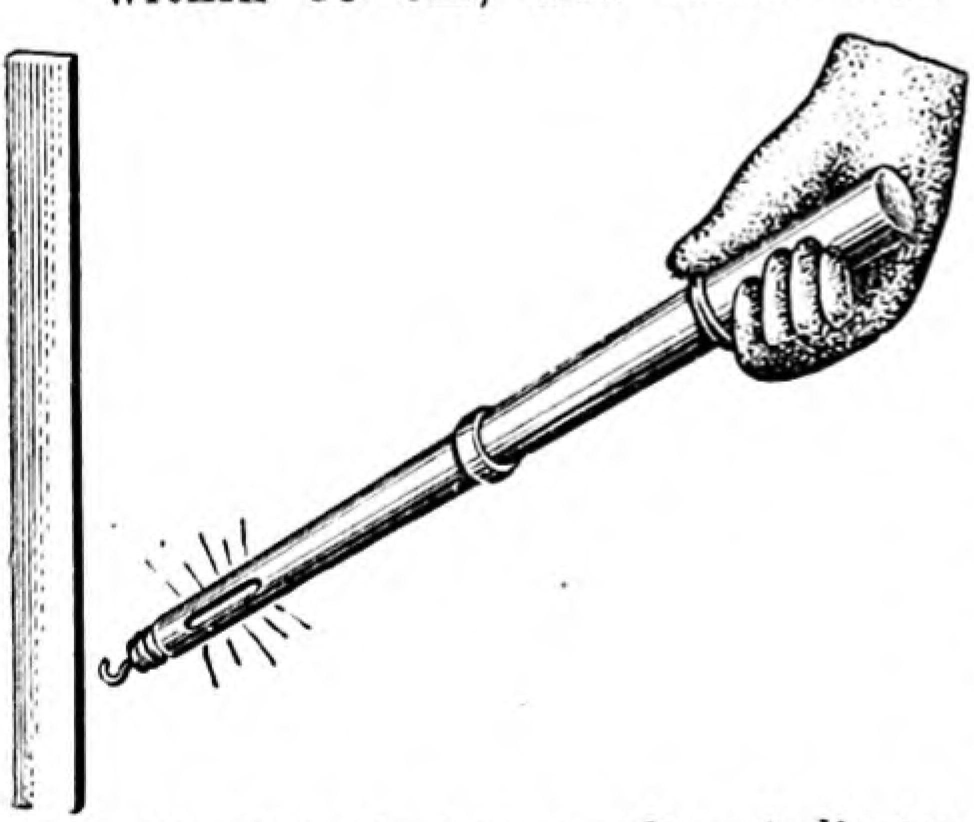


Fig. 341. Checking a voltage indicator.

After switch-out of the live parts, the attendant must make sure there is no potential by checking them with a voltage indicator.

Before doing such testing, the attendant has first to convince himself that the voltage indicator is in fit condition. He does this by watching if the indicator glows when brought up to some live part (Fig. 341).

To work with a voltage indicator, rubber gloves must be worn and rubber half-boots must be slipped on over the shoes.

All the terminals of disconnected equipment, as well as all six terminals of circuit breakers, have to be checked for the absence of potential by touching them with the hook end of the voltage indicator stick.

Another operation in this work is to prepare the portable safety-earthing conductor sets so that they are ready for immediate attachment. The safety-earthing sets have to be attached at all sides from which a voltage can be applied. Each set must be clearly visible from the place of work.

Attaching of the safety-earthing sets to the earthing bus circuit is done prior to checking for absence of potential. When the checking is completed, the safety-earthing leads can then be clamped to the de-energised current-conducting parts by means of an insulating, clamp-attaching stick, this being done

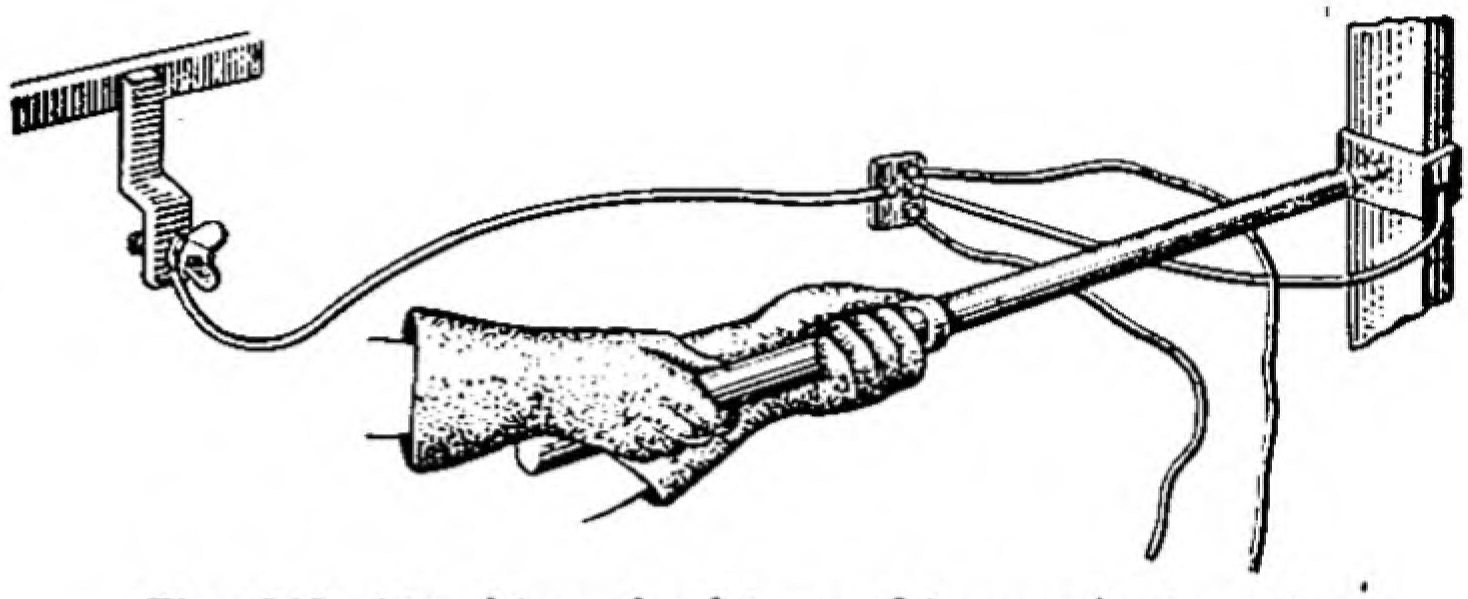


Fig. 342. Attaching of safety earthing-conductor set.

only on condition that the hands are protected with rubber gloves (Fig. 342). As a rule, two persons must take part in attaching safety-earthing sets.

When all the above operations have been completed, the shift attendant, his superior duty engineer and the repair team superintendent are obliged to check once again for completion of all prescribed measures for safety. Only after this can the repair team be allowed to enter the switchgear premises.

It is the duty of the attendant to show the repair team where the work is to be done and in the presence of every member of the team touch the de-energised parts to show that they have been switched out. He also shows the team which of the neighbouring parts have been left alive. Such parts must always be blocked off.

Disconnections within the installations should be made so that the necessary section is separated from all sides by isolators to provide thereby visual breaks in the circuit. For preventing any possibility of application of voltage to parts disconnected for work on them, the attendant is obliged to padlock or remove the handles of manually controlled isolator operating mechanisms, and also remove the fuses in both operative supply wires leading to remotely controlled circuit breakers. Such measures safeguard against possible appearance of high voltage upon disconnected parts.

Standard warning notices stating: "Do not switch on! Men at work!" must be hung on the operating-mechanism control handle of the circuit breaker by which the power can be switched into a line or installation where men are to work. When several teams have to work on such a line installation, the number of signs to be hung on the control handle must equal the number of teams employed in the work.

Danger notices must likewise be hung on the temporary guards and also on the screened-off live cells directly surrounding the place of work. They state: "Stop! High voltage—Danger!"

At the place where the work is to be performed "Work here" notices must be hung.

8. Resuscitation from Electric Shock

Quick action, resourcefulness and skill are the main factors for successfully rendering first aid to a victim of electric shock.

First immediately disconnect the power from the circuit the patient is in contact with. If he is located above floor or ground level, take measures to prevent him from falling.

If the installation cannot be quickly disconnected from power, immediately remove the patient from contact with the circuit.

When the circuit has a low voltage, this can be done by pulling the patient by his clothing. However, grasp the clothing where it is dry and out of contact with the body of the patient. The most convenient and safest way is to grasp a free fold of his clothes. Do not directly touch his body.

If the rescuer pulls the patient away from the circuit by the feet, he must first insulate his hands (by wearing rubber gloves, wrapping them with pieces of clothing or like material, etc.) in order not to risk receiving a shock through the damp boots (because of the nails, bootlace hooks).

Another way is to stand on a dry plank, bundle of dry clothing or any other nonconductive material. It is recommended that only one hand should be used.

When the accident has occurred by contact with a high-voltage circuit, the rescuer must wear dielectric half-boots and rubber gloves and remove the live parts with an insulating pole or insulating tongs.

If the patient has not lost consciousness, he must be sent to the hospital or closest point of medical aid, or be examined by a doctor directly at the place where the accident has occurred.

If the patient has lost consciousness, but continues to breathe, loosen the clothing about his neck, chest and waist to ease breathing and sprinkle his face with water. It is helpful to allow the patient to sniff ammonia spirit, warm and rub his body and provide plenty of fresh air. As in the above cases, immediately send for a doctor.

If breathing has stopped, or the patient breathes with pauses and spasmodically, immediately begin artificial respiration.

To begin artificial respiration, swiftly free the patient of clothing that will hinder breathing, open his collar; if he is wearing a muffler, remove it.

Free the mouth of all foreign objects. If the patient has false teeth, remove them.

The patient may have clenched his teeth but his mouth, nevertheless, must be opened. Do this by placing the four fingers of each hand at the rear corners of the lower jaw with the thumbs on the edge of the chin in order to move the lower jaw forward. The lower teeth should then come somewhat in front of the upper teeth in this forward position. If the mouth

cannot be opened by this method, a flat piece of wood or metal plate should be carefully inserted between the rear molar teeth and the jaws opened.

Two methods of artificial respiration are generally used. The first method is employed when only one person is available for rendering first aid. In such cases the patient must be laid on his abdomen with his face turned to one side and laid on one arm. Extend the other arm straightforward past the head. Place something under the face. If possible, draw the tongue forward.

The person rendering first aid must now do the following: kneel astride the patient at the thighs (Fig. 343) and place both palms on the lower ribs with the fingers extending round the sides. To the count of one, two, three swing your body forward on your straightened arms to gradually bring its weight to bear upon the ribs of the patient. This movement ensures an exhalation.

Fig. 343. Artificial respiration by first method.

Without removing the hands, quickly swing your body backward to release the pressure. This should result in an inhalation. After the count "four, five, six", gradually apply the weight of your body again.

Repeat each such complete period of respiration at the rate of 12 to 15 times a minute until the patient revives or a doctor arrives to take charge.

When assistants are on hand, employ the second method. It gives better results. This method, however, is more exhausting for the person rendering artificial respiration and he must be replaced from time to time.

To use the second method, do the following: lay the patient on his back with a bundle of clothing under his shoulder blades so as to make the head full backwards (Fig. 344). Clean

Fig. 344. Artificial respiration by second method (the exhale).

the mouth of saliva. Grasp the tongue through a handkerchief to pull it forward and hold it from falling backward and closing off the windpipe. Pull the tongue slightly downward towards the chin.

One of the men rendering aid must now kneel at the head of the patient, grasp his arms near the elbows and gently force them down against the chest of the patient to obtain an exhalation of air.

To the count of one, two, three (Fig. 345) raise and extend the

Fig. 345. Artificial respiration by second method (the inhale).

arms of the patient above his head to obtain an inhalation of air. The assistant must continue to hold the tongue forward.

If three persons can render aid, two men do the artificial respiration, one at each arm of the patient. The third man holds the patient's tongue.

When artificial respiration is carried out correctly, the passage of air through the respiratory path produces a sound similar to a groan. Any absence of such sound means that the tongue has evidently fallen too low. If this is so, slightly draw it forward.

If an arm or shoulder blade is broken, the second method cannot be used.

Always act gently when rendering artificial respiration. Application of excessive pressure or sudden movements may lead to forcing of food out of the stomach and blocking of the windpipe. The use of sudden and excessive force may also result in sprains, dislocation of joints and even in breaking of bones.

Never allow the body of a patient to become cold. For example, do not lay him directly on damp soil or on a cement floor.

Of great aid is to warm the patient by placing bottles filled with hot water or heated bricks at his feet.

If the patient fails to show signs of revival, never discontinue artificial respiration until a doctor arrives.

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